PROCEEDINGS

WORKSHOP
ON
LOW CLASS ROAD CONSTRUCTION
USING
VOLCANIC CINDERS AND PUMICE

SPONSORED BY THE U.S. FOREST SERVICE

PACIFIC NORTHWEST REGION

KLAMATH FALLS, OREGON

OCTOBER 5-6, 1970

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P R O G R A M

For
WORKSHOP
On
LOW CLASS ROAD CONSTRUCTION
USING
VOLCANIC CINDERS AND PUMICE

Molatore's Restaurant
Klamath Falls, Oregon

October 5-6, 1970

October 5

8:00	- 8:30	Registration	
8:30	- 8:45	Introduction and Announcements	L. Hendrickson
8:45	- 9:00	Keynote Address	W. Gano
9:00	- 9:30	Presentation of Low Class Road Rating System	J. Lund
9:30	-10:00	Break	
10:00	-10:30	Presentation of Region 6 Cinder Study	L. Hendrickson
10:30	-11:00	Presentation of Winema N. F. Dustfall Measurement Study	G. Wellman
11:00	-11:45	Presentation of Region 6 Pumice Study	J. Lund
11:45	- 1:00	Lunch	
1:00	- 3:00	Panel Presentation	T. Kerns

W. McIntosh - Lassen County, Calif.
L. Ficken - Weyerhaeuser Company
L. Stern - USFS, Region 5 (Calif)
R. Kennedy - Bly Logging Company
D. Hoerning - Klamath County, Ore.

3:00	- 3:30	Break	
3:30	- 5:00	Questions, Discussion and Summary	T. Kerns & Panel

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and.....John W. Lund

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and.....Stephan A. Barraclough

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FIELD TRIP ITINERARY

6 Oct 1970

8:00	Begin loading at Molatore's	
8:30	Leave Klamath Falls	
9:45	Arrive Pumice Test Road	(1)
10:30	Leave Pumice Test Road	(1)
11:00	Arrive Skellock Cinder Pit	(2)
11:30	Leave Skellock Cinder Pit	(2)
11:45	Arrive County Pit Site	(3)
	Lunch	
12:30	Leave County Pit Site	(3)
12:40	Arrive Clay Section-Kirk Road	(4)
1:00	Leave Clay Section - Kirk Road	(4)
2:00	Arrive West Section - EW Road	(5)
2:15	Leave West Section - EW Road	(5)
2:30	Arrive East Section - EW Road	(6)
2:45	Leave East Section - EW Road	(6)
3:00	Arrive EW Cinder Pit	(7)
3:15	Leave EW Cinder Pit	(7)
3:30	Arrive County Road Site	(8)
3:50	Leave County Road Site	(8)
5:00	Arrive Klamath Falls	

BRIEF DESCRIPTION OF FIELD TRIP
STOPS INDICATED ON ATTACHED MAP

- - - -

(1) Pumice Test Road (Bear Flat Rd #286)

Constructed summer 1969 by Forest Service forces. First mile from County road constructed as a test road. Stabilized with cement (5% by weight), cinder clay (30%), hydrated lime (5%), BS-120 asphalt road mix (15%), BS-120 penetration treatments (1.1 gal/sy and 1.6 gal/sy) and seal coats @ 0.3 gal/sy on portions of cement and lime sections. Approximately 3000 vehicles have traveled over the sections to date -- mostly light vehicles.

(2) Skellock Cinder Pit (off Rd #31043C)

Major source of cinders for road construction. Both black and red cinders available; originally covered with a mantel of pumice and clay (decomposed cinders). Used to surface Kirk Road and for stabilization of the pumice test road. The red cinders have an LAA = 32 and the black = 37. The cinder clay has LL = 35 and PI = 7. The maximum density (AASHO T-99) is approximately 92 pcf for the cinders.

(3) Klamath County Pit (Lunch Stop)

Location of source for chip seal on Silver Lake Road.

(4) Kirk Road

Surfaced with 6" of black cinders in 1967. Material did not set up on steeper grades and set up poorly on flat grades, mainly due to poor gradation.

In 1969 overlayed steeper grades with red cinders containing considerable clay from Skellock Cinder Pit, which improved the stability of these sections.

(5) E-W Road West Section

Road was originally surfaced with pit run material with oversized material either broken down or removed by hand. This oversize still lines the road.

In spring of 1970 the road was resurfaced with graded cinders(1 inch minus) which met Forest Service recommended cinder specifications. The material was run through a primary jaw and the oversized screened off.

Cinders were then processed on the road which consisted of mixing, watering and compacting with a vibratory roller Compaction was over 100% (T.99). Approximately 2500 vehicles have traveled this section since construction.

(6) E-W Road East Section

The road was constructed in 1968 and 1969 with the cinder surface completed in the summer of 1969. The specifications for the cinders called for a maximum size of 2½" without specifying intermediate sizes.

The cinders were produced by use of a primary jaw with oversized screened out and returned to the jaw.

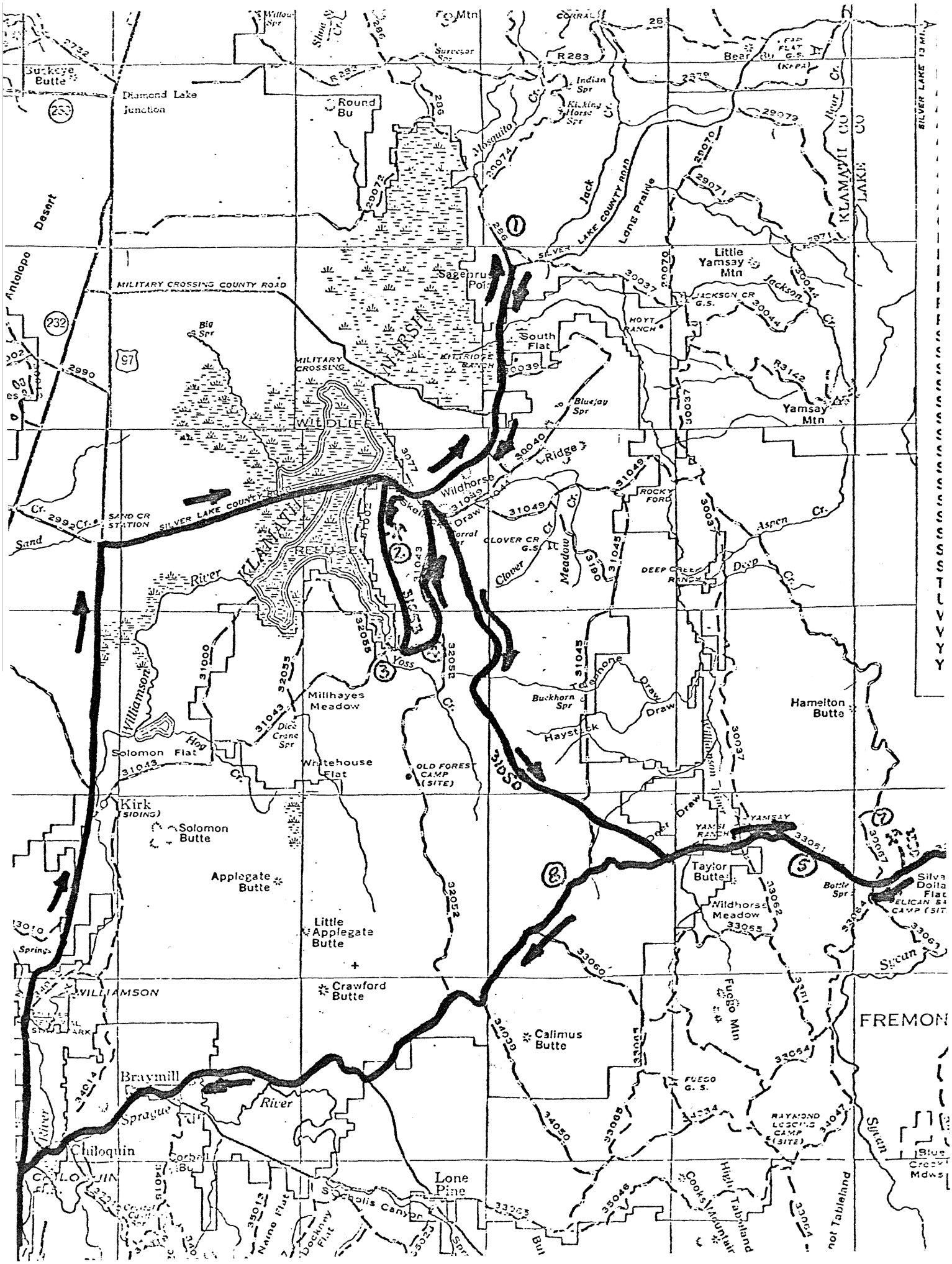
Cinders were processed on the road by mixing, watering and rubber-tired compaction.

(7) E-W Cinder Pit (off Road #3380)

Used to surface E-W Road. Some cinder clay was encountered in the pit and there appears to be some iron oxide binder present. The reject pile of basalt and harder cinder are from the 1970 construction of the West section of E-W road. Secondary crushing would be necessary to utilize this material.

(8) Head of the River Road (Klamath County # K600)

Paving completed in 1969 and chip sealed in 1970. Constructed with a crushed cinder base (1½"-), 6 inch - 1 foot deep. Covered with a crushed cinder leveling course (3/4"-), 2 inches deep. Paved with a 3-inch deep asphalt mat using 3/4"- crushed cinders and MC-800 at 23 gals/cy. Sealed with 200-300 pen asphalt and 1/2" - 1/4" crushed basalt chips.


Diamond Lake Junction
Round Bu
Indian Spr
Kicking Horse Spr
Mosquito Cr.
Jack
LAKE CO
KLAMATH CO
Long Prairie
SILVER LAKE COUNTY ROAD
Little Yamsay Mtn
Jackson Cr.
HOYT RANCH
South Flat
Bluejay Spr
Yamsay Mtn
MILITARY CROSSING COUNTY ROAD
Big Spr
MILITARY CROSSING
WILDLIFE REFUGE
Wildhorse Draw
Ridge
ROCKY FORD
Aspen Cr.
SAND CR STATION
SILVER LAKE COUNTY
Sand
Clover Cr.
Meadow
CLOVER CR G.S.
DEEP CREEK RANCH
Deep Cr.
KLAMATH
River
Williamson
Millhayes Meadow
Dice Crane Spr
Yoss
Buckhorn Spr
Hamelton Butte
Haystack
Solomon Flat
Hog Cr.
Whitehouse Flat
OLD FOREST CAMP (SITE)
Kirk (SIDING)
Solomon Butte
Applegate Butte
Little Applegate Butte
Crawford Butte
Taylor Butte
Wildhorse Meadow
Bottle Spr
Silver Dollar Flat
PELICAN BAY CAMP (SITE)
Sycan
WILLIAMSON
Calimus Butte
Fuego Mtn
FREMONT
Braymill
Sprague River
Chiloquin
Lone Pine
Cooks Mountain
High Tableland
RAYMOND LOGGING CAMP (SITE)
FUEGO G. S.
Naine Flat
Dockney Flat
Crystal Crk Spr
Rocky Point Bu
Not Tableland

WORKSHOP
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LIST OF REGISTRANTS

Name	Address	Position
Anderson, Gordon	Rogue River N. F., Medford	Civil Engineer
Barraclough, Steve	Oregon Technical Institute, Klamath Falls	Student in Environmental Tech
Brown, Dan	Francis Brown & Son, Inc., Klamath Falls	Manager
Clark, Joe	Medford Corp., Medford	Logging Manager
Coulombe, Arthur E.	Fremont N. F., Lakeview	Civil Engineer
Crabtree, Jesse A.	Oregon Technical Institute, Klamath Falls	Asst. Prof. of Civil Engr. Tech.
Davies, Cecil D.	Gifford Pinchot N. F., Vancouver, Washington	Supvry. Hwy. Engineer
Ficken, Lyle	Weyerhaeuser Co., Klamath Falls	Asst. Land Use Supervisor
Freese, Gary	Wenatchee N. F., Wenatchee, Wn.	Civil Engineer
Gano, Ward	Forest Service R6, RO Portland	Regional Engineer
Goddard, George	Deschutes N. F., Bend	Forest Engineer
Grubb, George E.	Douglas County Roseburg	County Engineer
Hammersley, Creal H.	Weyerhaeuser Co., Klamath Falls	Engineering Supervisor

Name	Address	Position
Harlan, Richard N.	Fremont N. F., Lakeview	Asst. Forest Engineer
Harris, Bob	Shasta Trinity N. F., Redding, Calif.	Civil Engineer
Hatch, Doug	Winema N. F., Klamath Falls	Supvry. Hwy. Eng. Tech.
Hendrickson, Larry	USFS R.O. -6 Portland	Civil Engineer
Hoerning, Dave	Klamath County, Klamath Falls	Dir. of Public Works
Horne, Jim	Rogue River N.F. Medford	Forest Engineer
Hunt, Robert W.	USFS Engineer Materials Investigation Branch Arcadia, Calif.	Supvry. Hwy. Eng. Tech.
Ifft, John A.	Bureau Land Management Medford	Forester
Johnson, Allan	Rogue River N. F. Medford	Civil Engineer
Johnston, Beryl	U. S. Forest Service R 5 Concord, Calif.	Supvry. Civil Engineer
Kennedy, Robert B.	Bly Logging Co., Klamath Falls	Partner
Kerns, Tom	Winema N. F., Klamath Falls	Forest Engineer
Kruchko, George	Klamath N. F., Yreka, Calif.	Civil Engineer
Lancaster, Gregory P.	Bureau of Land Management Medford	Forester
Lund, John W.	Oregon Technical Institute Klamath Falls	Assoc. Prof. of Civil Engr. Tech

Name	Address	Position
McClain, Mel	Harold Barclay Logging, Inc. Sisters	Logging Supt.
McDonald, Tom	Boise Cascade Corp. Klamath Falls	Logging Supt.
McDonough, Nick	Willamette N. F., Eugene	Sup. C.E.
McIntosh, Wm. D.	Lassen County Susanville, Calif.	County Road Commissioner
Maloney, E. W.	Modoc Lumber Co. Klamath Falls	Forester
March, Grant	Bly Logging Co. Klamath Falls	Partner
Margason, Greg	Lassen N. F., Susanville, Calif.	Forest Engineer
Mayberry, Gerald	Winema N. F., Klamath Falls	District Engineer
Nuttall, Stanley	Deschutes N. F., Bend	Civil Engineer
Pelzner, Adrian	U. S. Forest Service- WO Washington, D. C.	Civil Engineer
Phillips, Fred	Winema N. F., Klamath Falls	Construction Engr.
Robinson, Eldon	Jack Robinson & Sons, Inc. Bend	Owner
Sawyer, Robert W.	Umpqua N. F., Roseburg	District Engineer
Schwarzhoff, Chris	U. S. Forest Service R6 Materials Lab-Portland	Supvry. Materials Engineer
Schwulst, Russell J.	Modoc N. F., Alturas, Calif.	Forest Engineer

Name	Address	Position
Smeltzer, Duane A.	Medford Corp. Medford	Logging Engineer
Smith, Allen C.	Medford Corp. Medford	Timberlands Manager
Stern, Leonard J.	U.S.F.S. E.M.I.B. Arcadia, Calif.	Materials Engineer
Steward, John E.	Umpqua N. F., Roseburg	Materials Engineer
Tavernia, Robert R.	Ochoco N. F., Prineville	Civil Engineer Technicn.
Wellman, Gene	Oregon Technical Institute Klamath Falls	Chairman of Air Pollution Control Technology
Williamson, Ron	U. S. F. S. - R6 RO Portland	Materials Engineer
Wood, Harold W.	Winema N. F., Klamath Falls	Preconstruction Engine

PERFORMANCE RATING FOR AGGREGATE SURFACE ROADS

by

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Associate Professor of
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Oregon Technical Institute
Klamath Falls, Oregon

and

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USDA - Forest Service
Portland, Oregon

Presented at

Highway Research Board
Annual Meeting
Washington, D. C.
January 12, 1970

John W. Lund

ABSTRACT

Aggregate surfaced roads--especially those constructed with volcanic cinders, have performed with variable results. The U. S. Forest, in connection with forest development road construction, initiated a study to determine which parameters influenced the performance of cinders when used as a wearing surface.

A road rating system was developed, similar to the AASHO road test methods, to determine which were "good roads" and which were "poor roads" based on a o to 5 numerical rating scale. Forty-seven roads in Forests in South-Central Oregon were rated and statistically correlated with maintenance, rutting, watering, speed and traffic volume, by means of a multiple linear regression program. The resulting regression equation had a multiple correlative coefficient of 0.812, with rutting and speed being the most significant variables. The results are felt to apply to all types of aggregate surfaced roads, with the resultant numerical rating referred to as a performance index.

The information from this rating system will be used to recommend specifications for untreated surface course material.

PERFORMANCE RATING FOR AGGREGATE SURFACE ROADS

by

John W. Lund
Associate Professor
Oregon Technical Institute

and

Larry G. Hendrickson
Civil Engineer
USDA - Forest Service

One of the major sources of aggregates for low class roads in Central Oregon and Northern California is volcanic cinders (scoria). The use of cinders and the performance of cinder surfaced roads has been varied, with both good and poor results. The U. S. Forest Service began a study in 1968 to determine the parameters which influence the performance of volcanic cinders when used as a wearing surface for forest development roads.

The approach to this problem suggested an evaluation of the performance of existing untreated cinder roads to determine which were "good roads" and which were "poor roads" based on a numerical rating scale. This in turn was related to the physical properties of the cinders in the roadway and from the borrow pit. A survey of current literature and construction practice was also performed. These relationships, together with other field observations, were used to recommend specifications for selecting borrow material and for constructing quality control techniques. This paper is concerned only with the development of the performance rating procedure. The details of the entire study are presented in a U. S. Forest Service report from Region 6 (1).

A performance rating system (serviceability over a period of time) had to be developed since none existed for untreated aggregate roads. Serviceability (developed by the AASHO Road Test) was not felt to be applicable as the condition of an untreated road changes rapidly from day to day. This is especially true if a road is rated immediately before maintenance (its poorest condition) and immediately after maintenance (its best condition). Instead the performance of the road was considered and related to the maintenance period.

John W. Lund

BACKGROUND INFORMATION

An evaluation of the ability of a pavement or riding surface to perform its intended function has been attempted for many years, mainly in the form of a "good" or "poor" classification. These subjective terms obviously varied from rater to rater. In an effort to solve this problem, several systems using an objective evaluation based on a numerical scale were developed, utilizing such terms as performance rating, serviceability index, condition survey, and sufficiency rating. The end result was to somehow determine the beneficial and detrimental features affecting the performance of an existing road so that the detrimental properties could be avoided in future projects and the beneficial items used or improved upon to prevent failures and to upgrade the surface riding quality.

Unfortunately very little has been done concerning rating untreated or gravel surfaces. The necessary requisites of untreated surfaces have been documented and are: (2)

1. Stability - ability to support the superimposed loads without detrimental deformation;

2. Resist abrasive action of traffic;

3. Shed large portion of rain - since excess moisture may cause loss of stability:

4. Capillary properties - sufficient to replace moisture lost by surface evaporation; and

5. Low cost.

To achieve these requisites, the following items have been proven to be necessary.

1. Control of grading (AASHO M-61 specifications);
2. Control of Atterberg Limits in binder (AASHO: max LL = 35, PI = 4 to 9); and
3. MAX LAA = 40.

Roughness of untreated surfaces has also been studied (3). The circumstances that have been ascertained to be associated with the formation of potholes include:

1. Volume of traffic;
2. Width of road surface (related to item 1);
3. Type of surface material;
4. Condition of crown (steep favorable); and
5. Condition of shoulders.

Of these, the volume of traffic is perhaps the most important. The problem of rating untreated roads then becomes one of deciding which features of the roadway are to be considered in recognition that the purpose of a highway pavement is to provide a smooth riding surface supplying safety, comfort, and economy to the highway user (4,5).

The most important item appears to be riding quality. However, this poses a problem for untreated roads, since the riding qualities vary considerably with maintenance. When the riding quality becomes poor or reaches a certain critical point then the road is maintained and upgraded to its original conditions, (this may vary with available money, men or equipment). Thus, the evaluation of untreated surfaces varies from good to poor and then back to good. The logical means of evaluating riding quality then becomes a function of maintenance frequency and ease of maintenance with some consideration given to the severity of dusting. In addition, the type of rutting should be included such as washboard (transverse), erosion or wheel ruts (longitudinal), and potholes or local failures. The depth and spacing of washboards is generally constant and independent of the nature of material in which they occur (3).

The deterioration or required frequency in maintenance of a road is also dependent on the amount and type of traffic, and speed. The latter appears to be influenced by geometric design; i.e., the straighter the road the greater the speed and the faster the deterioration. However, sharp curves will cause lateral shoving of material and steep grades will present problems of sudden speed changes due to shifting and also traction problems (6).

The consideration of maintenance in serviceability and performance studies has been recognized (7).

> "Ride alone is not a criterion of pavement performance. It must be coupled with a knowledge of maintenance activity to be meaningful--any pavement can be made to have a smooth 'ride' if enough money is spent for

> maintenance activity. However, a smooth riding highway that is being maintained at excessive costs cannot be said to be performing satisfactorily."

In high type bituminous pavements, maintenance can be correlated with thickness increase due to patching and repair. For all types of pavements maintenance frequency or cost could be measured.

Traffic volumes, as indicated above, affect the maintenance frequency and riding quality of a road. Reports of traffic volume vs. wear vary. Ladd (1924) (3) reported that gravel roads subjected to a volume of not more than 200 to 300 vehicles per day remained practically free from washboard if occasionally dragged. As soon as the volume reached 400 to 450 vehicles per day, washboards developed very rapidly. Carpenter and Dana (1927) (3) found that 300 to 400 vehicles per day did not usually cause serious formation of washboards. Willis, Aaron, Lindberg (1942) (8) found that washboards may appear when the count is as low as 100 vehicles per day. Huang (1961) (3) speculated that, considering that weights and speeds of vehicles have been considerably increased during the past 30 years, a volume of 50 vehicles per day can probably be regarded at present as the average volume that would initiate washboarding in a fairly well constructed road even under favorable climatic conditions.

Relating the surface wear or maintenance responsibility attributed to various types of traffic has always presented a problem. The U. S. Forest Service, in an attempt to solve this problem, converts various types of traffic to equivalent units for assigning maintenance. Shares are based on the following (9):

1000 board feet hauled (round trip)

= 2 passenger vehicles (one way)

= 1 1/2 passenger vehicles w/trailer (one way)

= 2 cubic yards of rock or ore (round trip)

Since one truck load equals approximately 5000 board feet (net), then one log truck round trip is equivalent to 10 passenger vehicles (one way).

Opinions vary as to the validity of the above relationships; some Forest Service personnel would place more emphasis on loaded logging trucks as compared to passenger cars; whereas others feel high speed passenger cars, especially in the form of recreational traffic with campers and boat trailers, are more destructive than the above relationship indicates.

DEVELOPMENT OF RATING SYSTEM

It was decided to use a procedure similar to the AASHO Road Test methods (10) for the rating of untreated aggregate roads. The AASHO Road Test serviceability performance rating system appeared to be reliable and generally accepted by many transportation agencies. However, one major deviation was made in this study: the road was given a performance rating instead of a serviceability rating by the rater. Since the serviceability (rating at a particular time) varies considerably between maintenance periods, performance (a rating over a period of time) is used instead.

The rating of each individual road segement was obtained from three knowledgeable persons on the particular National Forest or Ranger District, such as the District Engineering Assistant, the Road Maintenance Foreman, the District Ranger, etc. Unfortunately, different personnel were used on each forest and even on each district as only the local people would have a good knowledge of how the particular road performed over a period of time. The authors were unable to rate the roads, since in most instances they saw the particular road only once or twice, which would not necessarily be the "average" condition of the surface.

The raters were asked to rate the particular road on the basis of the AASHO Road Test 0 to 5 scale (11). They were told to rate the road as to its ability to carry the existing traffic efficiently and conveniently under the average conditions of the road between maintenance periods, comparing the road with that of a high quality gravel surface.

The individual rating was called the performance rating (PR) and the average of the three values obtained for a particular road was called the performance value (PV).

The use of a performance rating has certain inherent advantages. Since the rating was an average over a period of time, requiring the rater to be a person familiar with the operations of the road over an extended period, it was not necessary for the rater to drive the road at the time the rating was made. In most cases the ratings were made individually

in the office. Thus, the individual ratings were convenient for the raters to make and less time consuming than a serviceability type rating. If necessary, the required ratings could be obtained by mail. One major disadvantage is that this rating may contain considerable bias.

The more difficult aspect of the rating system was to determine the properties of the roadway surface that could be used to predict the performance value (PV). This prediction based on measurable surface properties was necessary to standardize the performance value as the value for a particular road could vary from District to District as a new group of raters had to be used in each District. The predicted value, called the performance index (PI), could then minimize any bias included in the individual ratings.

Based on earlier discussions, maintenance was felt to be the basic parameter to relate the performance index. In addition both longitudinal profile and speed were felt to be important. Finally traffic volume, with considerations for weight, was suspected to affect the above mentioned items. All of the above quantifiable properties were considered based on experience derived by other investigators, as outlined in an earlier section.

The specific items thus evaluated were:

1. Maintenance frequency, in days;
2. Length of time for ruts, washboards or potholes to develop after maintenance, in days (so that they affect the efficient and safe operation of the vehicles using the road);

3. Interval between period of watering during the dry season, in days;
4. Maximum safe speed that can be maintained by the majority of vehicles during the average conditions of the road surface, in miles per hour;
5. The average number of traffic units (two way) per day over the road during the period of the rating, in units per day (9); and
6. The amount of logging traffic units (two way) as determined in item 5, in percent.

During the course of the study several other variables were investigated such as subgrade strength, surface strength, surface thickness, age since construction, and the effect of the roadway cross section and width. However, none of these items appeared to have any measurable relationship to the road rating.

So as not to introduce other unnecessary variables, the raters were asked to consider only a straight, nearly level and unshaded portion of road when assigning a performance rating value. It was felt that grades, curves and tree cover (affecting the moisture content of the road) would affect the rating and thus should be avoided if possible. The properties used in the performances index were obtained from experienced personnel on the forests familiar with the maintenance and operations of the individual roads. Again these values were obtained for a straight section as indicated above.

A total of 47 roads were selected for study according to the following locations:

5 roads in the Eastern portion of the Rogue River National Forest.

9 roads in the Western portion of the Fremont National Forest.

9 roads in the Southern portion of the Deschutes National Forest.

24 roads in the Winema National Forest.

The general location of the study area is indicated in Figure 1. In many cases the road was rated twice; once based on logging traffic during a recent timber sale, and a second time based on light passenger vehicle traffic. Thus, a total of 57 ratings were made. The results of the ratings and the associated properties used in the performance index are listed in Table 1.

Fig. 1

Table 1

The average of the ratings (performance value) and the road properties were then analyzed using a multiple regression computer program (BMD-02R). This program weights each property and enters it into a linear equation that best estimated the performance value based on a least squares analysis.

The single correlation coefficients between each variable and the performance value is listed in Table 2. Table 2

Many variations and combinations of variables were investigated, including the common logarithm of the variables, the square of the variables, and combinations of two variables multiplied together or divided by each other. The results of the best equation (highest multiple correlation coefficient) is as follows:

$$PI = 0.704 + 0.041S + 0.702 \log_{10}R - 0.040W/U + 0.022M/U$$

where:

PI = performance index;

S = speed in MPH.

R = rut development in days;

W = watering interval in days;

U = traffic units; and

M = maintenance interval in days.

The multiple correlation coefficient for the above equation is 0.812. However, ruts and speed alone contribute 0.768 to the coefficient, with the remaining variables increasing the correlation of the equation by only 4.4%. The steps in forming the above equation and the influence of each variable is indicated in Table 2. As indicated in this table the most important variable is the formation of ruts.

Using this latter equation, the PI of each road can be calculated. This value is then an estimation of the PV with the bias due to individual raters removed. A comparison between these two values is presented in Table 1. Review of these data shows that the regression analysis tends to eliminate the extreme ratings.

The photographs in Figures 2 through 5 are typical examples of the various ranges in road rating based on the PI. Figs. 2-5

COMMENTS ON ROAD RATING RESULTS

The significant variables used in the final equation to predict the PV were generally those expected, such as speed and rutting. These variables were expected to be significant, based on the experiences of other writers. The fact that the variables maintenance, traffic units, watering and percent of logging traffic were not significant was somewhat unusual and unexpected.

The reason for these departures from the expected is as follows:

a. With increase in traffic volume (logging operations in most cases) more emphasis was placed on maintaining a smooth surface. As a result, the road performance actually improved with use through additional compaction, blading, and watering. Under low traffic volumes the road was often only maintained once a year after spring thaw. Thus, maintenance frequency and traffic volume was more of a function of use rather than road performance.

b. The effect of logging traffic and recreational traffic in road performance is actually not well defined; the use of traffic units is only an estimation.

c. The small correlation between traffic volume and performance value (CC = 0.024) indicates that the volume of traffic using a forest access road is independent of its condition, since there is often no alternate road.

The use of the multiple correlation coefficient indicated that 34% of the variations in PV was unexplained. This is more than likely due to the variation in raters from forest to forest and is the reason for using the PI rather than the PV.

CONCLUSIONS AND APPLICATIONS

Even though the system was developed using cinder surface roads, several crushed aggregate and volcanic pumice roads were also rated (see Table 1). Thus, the study is felt to be applicable to all types of aggregate surfaced roads.

With one or two exceptions, the calculated performance index (PI) for each road was felt to be reasonable by Forest Service personnel (i.e., the poorer roads on the Forests received low PI's and the better roads the higher values).

referenced to a period of time, the maintenance interval being the most logical to use. A rating system based on a 0 to 5 numerical scale was used and was correlated with maintenance, rutting, watering, speed and traffic volume. Speed and rutting frequency were found to be the most significant parameters. Traffic volume was not found to be a significant factor; however, perhaps some means other than the U. S. Forest Service unit system should be investigated.

The advantage of this rating system is that no elaborate equipment is required to rate the road, as only maintenance and traffic data are needed. This is in keeping with the level of service and cost of construction for this low class of road. Expensive and sophisticated measuring equipment is only justified for high type roads.

REFERENCES

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TABLE I
ROAD DESCRIPTION AND RATINGS*

Road No.	PV	PI	Speed mph	Ruts Days	Maint Days	Water Days	Traffic Units /Day	Percent Log
Winema N. F.								
1. 361	2.0	2.6	25	14	600	300	15	20
2. 3660	3.2	3.0	35	30	300	300	25	40
3. 350	2.8	2.6	25	21	120	300	100	0
4. 3633	3.1	2.8	30	30	120	300	50	0
5a 3700	4.6	4.2	50	300	300	300	20	0
5b 3700	4.6	3.3	50	5	3	2	70	71
6. 350D	4.8	4.5	50	300	7	1	50	90
7. 3790	3.8	4.5	50	300	7	1	140	90
8. 358	3.7	4.5	50	300	7	1	220	90
9a. 31043(N)	1.5	2.3	30	14	180	300	20	0
9b 31043(N)	1.5	2.3	30	4	4	2	61	82
10a 31043(S)	2.7	2.3	40	4	180	300	16	62
10b 31043(S)	2.7	3.0	40	10	8	4	61	82
11. 35010	2.5	2.9	40	7	7	1	150	67
12a 3190	2.7	3.1	45	30	90	300	20	0
12b 3190	2.7	2.7	30	14	14	7	77	90
13a 31049(W)	1.7	1.9	35	7	180	300	10	0
13b 31049(W)	1.7	1.5	20	1	7	7	61	82
14. 34015	2.7	2.4	45	14	90	300	10	0
15. 31049(E)	1.5	2.5	45	14	180	300	10	0
16a 33061	3.2	3.1	50	3	7	1	285	88
16b 33061	3.2	3.3	50	6	30	7	120	83

* Refer to pages 9 and 10 of text for explanation of column headings.

Road No.		PV	PI	Speed mph	Ruts Days	Maint Days	Water Days	Traffic Units /day	Percent Log
17a	2731[a]	4.2	3.8	45	90	90	300	76	0
17b	2731[a]	4.2	3.5	35	90	90	1	131	38
18.	2652C[a]	4.6	4.1	50	300	180	300	20	0
19.	286	2.0	2.1	25	4	90	90	19	0
20.	286[b]	2.2	1.6	30	1	0.5	300	37	68
21a	R283	3.5	3.8	40	180	90	90	11	68
21b	R283	3.5	2.8	40	5	90	90	30	0
22.	R2971	2.3	1.7	20	5	180	180	10	0
23.	29079	2.5	1.9	25	5	180	180	10	0
24.	30037	2.3	2.7	45	2	90	90	72	14
Deschutes N. F.									
25.	1821	2.3	2.8	40	7	100	300	80	10
26.	1915	4.7	4.2	45	300	300	300	50	0
27.	1808(W)	2.7	2.8	35	10	100	300	150	30
28.	1808(N)	3.2	3.4	50	10	100	300	200	30
29.	217	2.7	3.1	45	7	150	300	125	15
30.	2022(W)	1.8	2.1	30	30	150	300	10	30
31.	2022(E)	3.0	2.4	30	5	2	1	340	88
32.	2016[d]	2.5	3.4	45	21	150	300	80	50
33.	2221	1.8	2.8	35	10	75	300	350	10

Road No.		PV	PI	Speed mph	Ruts Days	Maint Days	Water Days	Traffic Units /day	Percent Log
Rogue River N.F.									
34a	3520B	2.2	2.5	35	3	60	60	110	90
34b	3520B	2.2	2.4	35	3	120	120	35	71
35.	344C	3.5	3.3	40	30	120	120	40	0
36.	3520M	3.7	3.1	40	14	80	80	40	0
37.	3317	2.7	3.2	40	28	240	240	25	0
38a	3520	3.2	3.1	40	14	80	80	25	0
38b	3520	3.2	2.9	40	7	60	60	35	34
Fremont N.F.									
39.	30038(N)	3.7	3.7	40	100	70	70	34	90
40.	30038(C)[c]	4.7	3.9	45	100	70	70	34	90
41.	30038(S)	3.0	2.9	40	7	70	70	34	90
42.	3312	3.0	2.9	40	7	7	7	131	90
43.	3610	2.7	3.1	35	42	240	240	31	90
44.	335	4.0	3.1	40	42	240	240	10	90
45.	379(S)	4.3	4.1	40	300	80	80	116	90
46.	379(N)	3.5	2.9	40	300	1	1	116	90
47.	3609	3.0	2.8	50	30	120	120	80	90

Note: All roads are cinder surface except:
- a gravel road (crushed basalt)
- b pumice road
- c clay binder added to cinders
- **d pit run - glacial outwash (basalt)**

TABLE 2
PERFORMANCE INDEX EQUATIONS

Formation of Equation

Step 1: $PI = 1.871 + 0.916 \log_{10}R$
$MCC = 0.685$

Step 2: $PI = 0.491 + 0.043S + 0.699 \log_{10}R$
$MCC = 0.768$

Step 3: $PI = 0.846 + 0.037S + 0.733 \log_{10}R - 0.025\ W/U$
$MCC = 0.805$

Step 4: $PI = 0.704 + 0.041S + 0.702 \log_{10}R - 0.040\ W/U + 0.022\ M/U$
$MCC = 0.812$

Properties of Individual Variables

Variable	Mean	Standard Deviation	Correlation with PV
Performance Value	3.0	0.9	1.000
Ruts	62.0	102.0	0.647
Water	158.1	127.4	-0.226
Maintenance	110.6	104.7	-0.066
Speed	38.8	8.2	0.604
Units	75.2	77.9	0.024
Percent Logging Traffic	42.2	38.9	0.142
$\log_{10}$(Ruts)	1.26	0.68	0.685
Water/Units	6.83	8.93	-0.294
Maintenance/Units	5.19	7.65	-0.207
$(\text{Speed})^2$	1575.9	611.4	0.612
$\log_{10}$(Units)	1.64	0.40	0.229

Figure 2

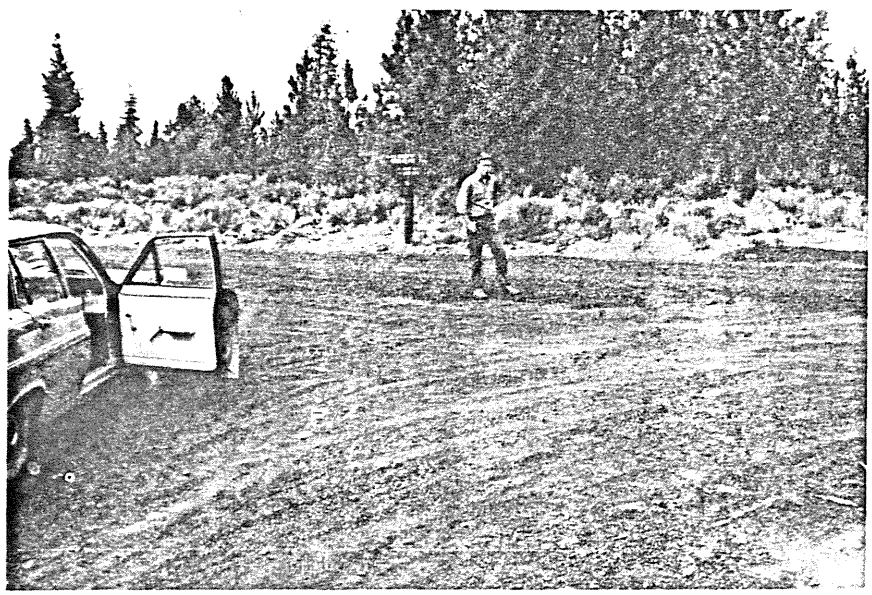

Figure 3

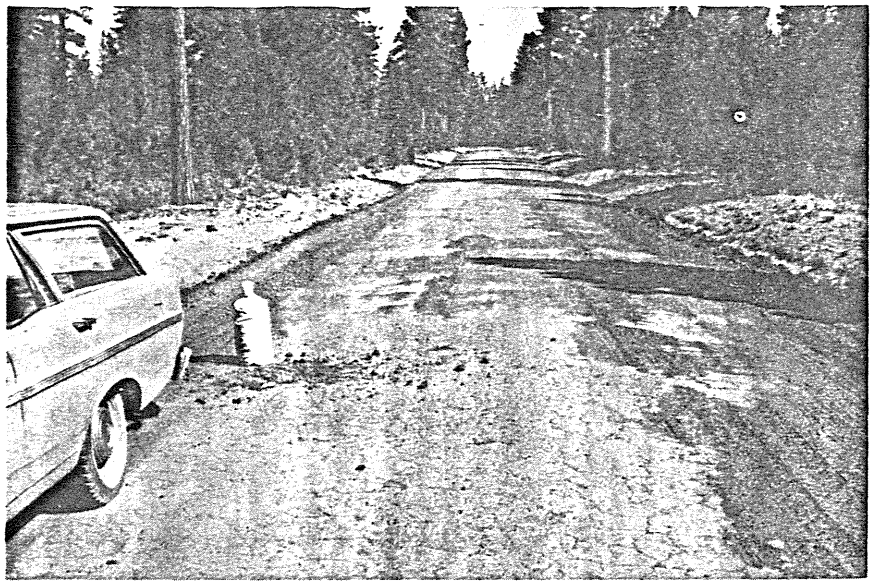

Figure 4

Figure 5

NOT FOR PUBLICATION

CONSTRUCTION SPECIFICATIONS FOR CINDERS USED AS ROAD SURFACING AGGREGATE

by

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Presented at

Highway Research Board
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Washington, D. C.
January 1970

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ABSTRACT

The purpose of this study was to determine parameters which influence the performance of volcanic cinders when used as a wearing surface for unpaved forest access roads. The steady depletion of good, high type aggregate sources has brought about renewed interest in other aggregate types, making this study particularily timely.

A literature review, correspondence, and personal interviews were conducted to determine existing use and performance of cinders. A road rating system was developed, similar to the AASHO road test method, to determine which were "good roads" and which were "poor roads" based on a 0 to 5 numerical rating scale. Thirty of the rated roads and the corresponding cinder pits were sampled and the material tested in the laboratory. The physical properties of the cinders were then statistically correlated with the road rating. It was found that density, gradation, durability, and plasticity were the most significant independent variables. Based on these results, specifications for untreated cinder surface courses have been developed. These include: 1) a minimum of 100 percent compaction relative to AASHO T-99; 2) gradation limits of 100 percent passing the 1 inch, 80 - 95% passing the 3/4 inch, 35 - 60% passing the #4, 22 - 45% passing the #10, 8 - 25% passing the #40, and 3 - 12% passing the #200; 3) a plastic index value between 2 - 10; and 4) a maximum Los Angeles Abrasion value of 50 prior to processing. In most cases this will require crushing of the harder (purple, gray, and black) type cinders.

CONSTRUCTION SPECIFICATIONS FOR

CINDERS USED AS ROAD SURFACING AGGREGATE

by

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and

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Volcanic cinders occur in many areas of the world and are particularly common in Central Oregon--the location of this study. The Forest Service of the U. S. Department of Agriculture builds many miles of untreated aggregate surfaced roads in the states of Oregon and Washington. In the Central Oregon area the use of volcanic cinders to surface those roads is very common. The performance of cinder surfaced roads has been varied,

with both good and poor results. The general trend among many highway agencies is to avoid their use. However, the steady depletion of good, high type aggregate sources has brought about renewed interest in other aggregate types, including volcanic cinders. Present usage of volcanic cinders is primarily for low class roads, either untreated or with a light asphaltic surface treatment.

PURPOSE OF STUDY

The purpose of the study was to determine the parameters which influence the performance of volcanic cinders when used as a wearing surface and base course for forest development roads. The approach to this problem suggested an evaluation of the performance of existing untreated cinder roads to determine which were "good roads" and which were "poor roads" based on a numerical rating scale. This in turn was related to the physical properties of the cinders in the roadway and from the borrow pit. Included was a survey to determine current usage and associated problems involved in the use of cinders as road aggregates.

These relationships, together with other field observations, were used to recommend specifications for selecting borrow material and for construction quality control techniques.

This paper is concerned with the relationship between cinder properties and road surfacing performance. The details of the entire study giving the background of the road rating system and the results of the survey to determine current usage are presented in a U. S. Forest Service report from Region 6 (1).

Larry G. Hendrickson

BACKGROUND INFORMATION

Cinders, as referred to in this report, are a pyroclastic material associated with volcanic activity (2,3). Fragmented material of this type is generally classified according to size. Pieces larger than approximately ten inches (256 mm) in diameter are called blocks or breccia if angular and ejected in a solid state, and bombs if ejected in a plastic state; thus producing a roundish or ellipsoidal shape with twisted ends. Pieces between ten inches and 1/16 inch (4 mm) in diameter are called lapilli or cinders. Particles finer than approximately 1/16 inch in diameter are called ash or dust (4).

A cinder, unlike most rocks, does not have a set mineral or chemical composition as it is mainly a textural classification of rock. It may be either acidic (light colored consisting principally of quartz and feldspars) or basic (dark colored consisting principally of ferromagnesian minerals with no quartz). Color reflects the conditions prevalent during formation (i.e., temperature or oxygen available) and weathering. Oxygen deficient cinders are darker in color, whereas red or brownish cinders generally indicate weathering and are located in the upper zone of a deposit. Minor accessory minerals such as iron may also contribute to the coloring of the cinder.

Scoria is a term used to describe any volcanic ejecta that is rough, sharp and vesicular, either pyroclastic material or the upper surface of some lava flows. It is commonly black or reddish and principally basic in composition. The term is often used to include cinders.

Cinders are located throughout the world. The main areas in the United States are Central Oregon, east of the Cascades, northern and eastern California, Arizona, New Mexico, and Hawaii. Foreign countries include New Zealand, Japan, Turkey, Mexico, Central America and the Caribbean. In foreign countries the terms scoria, scoriae, volcanic agglomerate, or grits are more used instead of cinders, especially by British Road Research Laboratory reports (5,6,7).

Current Practice and Experience

The details of this portion were given by Lund and Hendrickson (8). A summary is presented here for simplification.

Almost all agencies will avoid the use of cinders if other sources of mineral aggregate are available. When used, cinders are applied as surfacing material primarily on unpaved roads, such as logging, forest access and low traffic roads. On higher type roads cinders are used as sub-base and base material and for asphalt stabilized surfacing.

The best results with pit run cinders have been with the softer types (generally the red colored types; average LAA* in the 40's). The harder types (purple, gray, and black; average LAA* in the 30's) lack fines, and thus are unstable (Figure 1). When crushed, the harder types perform more satisfactorily, since the necessary fines are obtained and thus the surface will better withstand the abrasive effects of traffic. In addition, the rough riding quality due to the pit run oversized material is eliminated.

Fig.

* Resistance to Abrasion of Coarse Aggregate by use of the Los Angeles Machine - AASHO T-96.

Grid rollers are popularly used for breaking the larger pieces and for compaction. The effectiveness of this type of roller for compaction is questionable. Steel wheel, rubber-tired and vibrating rollers appear to achieve better results, as does compaction from logging and other heavy truck traffic.

With increasing traffic, road construction and pavement thickness upgrading, and the lack and depletion of good mineral aggregate sources, the use of cinders is being investigated in more detail. Many agencies feel cinders can be used effectively with the proper gradation and other quality controls. Asphalt treatment will probably give the best road surface and the most economical maintenance over an extended period.

CORRELATION OF CINDER PROPERTIES WITH ROAD SURFACING PERFORMANCE

Development of the Rating System

A road rating system was developed, similar to the AASHO road test methods. A major differe iation being that for this study the roads were rated over a period of time, hence the roads were given a performance index (PI) rating rather than a serviceability rating. Forty-seven roads were rated on a scale from 0 to 5 with performance increasing with increasing rating values (Figures 2 and 3). This rating was performed by people familiar with the long term serviceability of the road. After the rating was obtained it was correlated with maintenance frequency, rutting, watering, speed, and traffic volume by means of a multiple linear regression

Fig. 2.

computer program. The resulting regression equation had a multiple correlation coefficient of 0.812. This equation was then used to determine the performance index of the various roads which was, in essence, the performance rating with the individual rater's bias removed. Complete details of this rating technique can be obtained by referring to the U. S. Forest Service report (1).

Road and Pit Sampling Program

Once the road rating system, using the PI, was established, the next step was to select typical examples of roads within each rating group and sample the surface material. A total of 30 roads and their corresponding borrow pit source were sampled, including 15 in the Winema National Forest, and 5 each in the Fremont, Rogue River, and Deschutes National Forests. The general location of the sample sites is indicated in Figure 4. Fig

The purpose in sampling these roads and pits was to determine physical properties that could be identified with roads of high performance (PI) and those associated with low performance, or more specifically the correlation between performance and physical property. All roads were constructed of pit run material.

Field Procedure - The testing program consisted of two parts: field sampling and testing, and laboratory testing. The field sampling and testing portion involved first selecting a straight section of the rated road and obtaining approximately 150 lbs of material (2 sample sacks). This was obtained from a trench dug at least half way across the road and through the majority of the surface course (approximately 4-6 inches deep). In addition, the following field tests were performed:

a. In place density using the Washington Densometer;

b. In place moisture content using the Speedy Moisture Tester;

c. Color identification; and

d. Penetration test of surface and base material (later discontinued as there appeared to be no correlation).

Next the pit site was located and a 75 lb. sample (1 sample sack) was obtained from the approximate area in the pit where the road sample was obtained during construction. Obtaining a related sample was sometimes difficult due to mixing of pit material and subsequent use of the pit for other construction projects.

Laboratory Testing - The samples were sent to the Forest Service Regional Office in Portland, and in turn sent to the Federal Highway Administration laboratory in Vancouver, Washington, or the Oregon State Highway Department laboratory in Salem. Splitting of the work was necessary due to the volume of testing involved and the time requirements. Some additionsl testing was also performed at the Forest Service Engineering Materials Laboratory in Portland, Oregon.

The following tests were performed:

A. Road Samples

Test Description	Test Method
Los Angeles Abrasion	AASHO T-96
Specific gravity of fines	Calif. 208B
*Unit weight, dry rodded	

Test Description	Test Method
*Unit weight, loose	
Plasticity Index	AASHO T-90
Liquid Limit	AASHO T-89
Sand Equivalent	AASHO T-176
Oregon Air Degradation	OSHD
Moisture-density relationship	AASHO T-99 D
Gradation (dry sieve analysis)	AASHO T-27

B. Pit Samples

Test Description	Test Method
Los Angeles Abrasion	AASHO T-96
*Unit weight, loose	
Plasticity Index	AASHO T-90
Liquid Limit	AASHO T-89
*Oregon Air Degradation	OSHD
Gradation (dry sieve analysis)	AASHO T-27

*Only on samples sent to Oregon State Highway Department.

In addition the following calculations were performed:

(1) Coefficient of uniformity (C_u) for both road and pit gradation;

(2) Coefficient of curvature (C_c) for both road and pit gradation; and

(3) Relative compaction of road sample (as compared to maximum density).

Several points should be made in regard to the test results.

a. Los Angeles Abrasion Test. The actual values for the LAA appear to be very good (low values) and this is due in part to the volume of material used in running the test. The standard charge is 5000 grams of material. With the low bulk specific gravity of cinders a greater volume of material is used than would be normally utilized (9). Since this study considers only cinder aggregate, relative values between various cinder samples should be acceptable for use in the analysis.

b. Specific Gravity Test. Unfortunately this test was run in a Le Chatelier flask, (Calif. 208B), thus only material passing #4 sieve was used and the apparent specific gravity is determined. As a result, the values were very uniform, whereas values for the coarse portion would probably have been more meaningful.

c. Plasticity Index and Liquid Limit. In most cases the cinder had very few plastic fines, thus giving no plastic limit. However, the liquid limit could be determined for most samples (often only by one point and extrapolation) and thus was reported as it appeared to give good correlation.

Correlation with Performance Index - The reults of the field sampling and laboratory testing were compared with the performance index (road rating) by means of the multiple regression program. Nineteen independent variables

from road tests and twelve independent variables from pit tests were considered. These variables are listed in Table 1 together with their average value, standard deviation and correlation with the performance index. Table 1

According to the regression program, the most significant variables (with correlation coefficients above 0.3) in decreasing order of importance are:

Variable	Correlation with Performance Index
Relative Compaction	0.395
Plasticity Index	0.392
Percent passing #4	-0.341
*Percent passing 1.5"	0.328
Percent passing #10	-0.325
Coefficient of Curvative	0.323
Oregon Air Degradation - H	0.319
Percent passing #40	-0.312
*Percent passing 3/4"	0.310

*Indicates sample results from pit source.

Using ten variables the multiple regression equation becomes:

PI = - 5.65 + 0.06 (P) + 0.05 (RC) + 0.08 (OA-H) - 0.04 (OA-20) + 0.06 (PP1.5) - 0.07 (PP4) - 0.24 (Color) + 0.09 (PP10) - 0.02 (PUW) + 0.30 (CC)

Where:

PI = Performance Index;

P = Plasticity Index;

RC = Relative Compaction;

OA-H = Oregon Air Degration - Sediment Height;

OA-20 = Oregon Air Degradation -% passing #20;

PP1.5 = Percent passing 1 1/2" from pit;

PP4 = Percent passing #4 from pit;

Color = Cinder color (red = 2, black = 1);

PP10 = Percent passing #10 from pit;

PUW = Loose unit weight of material from pit; and

CC = Coefficient of curvative from road.

This equation has a multiple correlation coefficient of 0.854. Individual equations were also determined for each of the nine most significant variables. The equations and the individual correlation coefficients indicate the relationship between the physical test property and the performance index (rating). Unfortunately, 24 of the 32 roads had performance index within the relatively narrow range of 2.1 to 3.5; with only two roads rated below this range. Thus, the regression analysis gave the greatest weight to this range, resulting in most of the regression lines having very steep slopes.

Comments - Several important trends were noted when comparing the test results and the performance index and are summarized below.

Larry G. Hendrickson

1. Road Tests

a. Compaction: relative compaction is very important whereas the maximum density is not.

b. Gradation: The coefficient of curvature varies directly with the performance index (i.e., gradations with a concave shaped curve on a semi-log graph are associated with the higher performance index).

This is also reinforced by the trend of less material passing #4, #10, and #40 sieve with higher performance index; the value for the other sieves appears not to be significant.

c. Plasticity: The significant characteristics of the fine material appear to be increased plasticity index, liquid limit, sediment height in the Oregon air degradation test and decreased sand equivalent with increasing performance index (i.e., cohesive binder is desirable).

d. Abrasion: The LAA value varies inversely with the performance index (i.e., harder material with less abrasion is desirable).

2. Pit Tests

a. Gradation: Increased percentages passing the 1-1/2" and 3/4" sieves is desirable (i.e., less large size material).

b. Abrasion: Decreased LAA value is desirable.

Larry G. Hendrickson

Recommended Specifications and Field Quality Controls

Based upon the physical test results, the cinder characteristics that appear to be significant are:

1. Compaction
2. Gradation
3. Plasticity
4. Resistance to Abrasion

Using these characteristics, the following specifications are recommended for the construction of cinder wearing surfaces.

1. Compaction - in all cases the final constructed surface should be compacted to at least 100% of standard compaction (AASHO T-99). This should extend to a depth of 6 inches below the surface. In most cases, it is recommended that a vibratory compactor be utilized, or as an alternate a pneumatic roller. Sheeps-foot and grid rollers should be avoided. Steel wheel rollers can be used for finish or proof rolling.

2. Gradation - The maximum-sized particle should be 1 inch in diameter in the finished surface. In certain cases, this size could be increased to 1-1/2 inches at the pit source, as some degradation will take place in the construction process. The following in place road gradation is recommended. (Based on dry sieving similar to AASHO T-27 - with a maximum shaking time of 5 minutes).

Sieve Size	Percent Passing
1"	100
3/4"	80 - 95
#4	35 - 60
#10	22 - 45
#40	8 - 25
#200	3 - 12

These limits will provide a dense gradation.

This gradation is somewhat similar to AASHO M 147-55, grading C, and U. S. Forest Service Item 151, grading B, Item R151, grading C, and Item R150, grading C-1. The gradation recommended in this report differs somewhat for the above-mentioned specifications, having a smaller percentage passing in the #4 to #40 range to allow for subsequent degradation of the cinders. Local practice may indicate that the standard specifications listed above are adequate.

It is realized that in place road gradations are often difficult to estimate based on pit sampling. The best technique for sampling cinder pits is to obtain as representative a sample as possible (i.e., for the portion of the pit to be used, or a blended sample). Based on results from this study, the pit gradation should have approximately 5% less passing a given sieve (below the 3/4" size) than is desired for the finished product on the road. This allows for degradation in transporting and compacting the cinders. This value will be approximately 10% for the softer red and brown cinders.

The recommended gradation requirements could be met by selected blending and scalping at the pit source. However, in some cases it may be necessary to run the material through a primary crusher with some selective screening.

Control of gradation is felt to be extremely important as too much large material (above 1 inch size) causes a rough riding surface, and too much little fines will cause excessive and early washboarding and rutting.

3. Atterburg Limits - The material passing the #40 sieve should have the following characteristics:

Liquid limit	35 maximum
Plasticity Index	2 - 10

Based on the trends illustrated by the test results, the following test would give an indication of the required plasticity.

Sand equivalent	50 - 30

This value should not however be used as a specification requirement as it measures somewhat different properties of the fine material.

This requirement of plasticity is felt necessary to replace evaporated surface moisture through capillarity. In most cases, cinders do not produce this plasticity, thus requiring the addition of plastic binder.

This binder may be available as a cap of weathered cinders over the cone, or can be generated in some cases by watering, mixing and compaction of the softer brown and red cinders. A pulvemixer attached to a small tractor would perform an effective job of blending the cinders and plastic borrow material.

In some pits, the presence of an iron oxide binder will give a satisfactory binding action in the road. If this is the case, the plasticity requirements could be waived.

If immediate paving of the cinder surface with an impervious mat is anticipated, then the plastic material should be avoided. If paving is contemplated at a later date, then lime, asphalt, cement or other additives should be considered to reduce or eliminate the plastic characteristics at this time.

4. Resistance to abrasion - Maximum pit LAA of 50 should be used to prevent excessive degradation of the material in the road surface, as excessive fines will cause early washboarding and rutting. With pit run material, this degradation was necessary to generate sufficient fines for binder. However, with the recommended limits on gradation, this will no longer be necessary or desirable.

5. Conclusion - In most cases the harder cinders (purple, gray, and black colored ones) should have less degradation and provide a better riding surface over a longer period of time. However, this type of cinder

usually lacks the necessary fines and thus some crushing is required to meet the recommended gradation limits. The softer cinders (red and brown colored ones) sometimes have excessive degradation, thus care must be exercised in selecting the necessary gradation. The LAA requirement will eliminate the use of most of the softer types.

In some pits, where several cinder colors are available, blending of the harder and softer types may produce the necessary gradation and plasticity to provide an adequate riding surface.

SUMMARY

The foregoing analysis shows that cinders behave much as any other granular material when used as an untreated road surface. The study did reveal several modifications were desirable to standard specifications to better fit the properties of cinder aggregates. The test data indicate a LAA value of 50 would be more appropriate than the usual limit of 40. The mean of all LAA values is 46.7 percent loss, with a standard deviation of 10.6 when sampled from the pit. Therefore a maximum allowable of 40 is too restrictive. The test data show that both the plastic index and the gradation are very important for good performance. The gradation should ideally be somewhat on the coarse side of the gradation band to allow for subsequent degradation under traffic.

Relative compaction was also found to be very important, which further emphasizes that cinders behave much as any other granular material used as a road aggregate.

Larry G. Hendrickson

Reference to Table 1 shows a minor correlation (low value) between LAA and performance index (PI) and a positive, strong correlation between the Oregon air degradation "H" value and PI. Yet it is recommended that the LAA be used as a control test rather than the Oregon air degradation. This is explained as follows; high quality aggregate gives low Oregon air H values. Since this study showed a positive correlation between H and PI, the statistics indicate the poorer quality material yields higher PI values! This must, however, be considered in light of the fact that for all the roads studied the surfacing was placed with almost no gradation control and they were almost always lacking in fines. Therefore, when the material had a high H value, the cinders tended to break down under watering and traffic to produce the needed fines. Thus, there was a strong correlation between H value and PI. The recommendations in this report are to control the gradation before placing the material, consequently the desirability of having a high H value is no longer valid. There was a negative correlation between the LAA and PI, therefore, a specification for LAA is recommended. If a similar study were performed on roads where cinders were applied under a controlled gradation specification, it is felt by the authors that the LAA test would show a much stronger negative correlation. For this reason, and the obvious need to specify a material that will tend to hold its gradation, the LAA test is recommended. The maximum allowable limit was based upon the mean and the standard deviations of the test results.

In closing, it is mentioned that the specifications recommended are reasonable, based on test results of typical cinders in Central Oregon and the proven, accepted practice for aggregate surfacing control. The typical specifications when inserted into the regression equation yield a Performance Index over 5.0, which is an indication the criteria are consistent with the test results.

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TABLE 1

CORRELATION OF ROAD AND PIT TEST VARIABLES

Road Test Results

Variable	Mean	Standard Deviation	Correlation with PI
Sand Equivalent	49.4	24.0	-0.130
Los Angeles Abrasion	43.8%	10.4	-0.099
Maximum Density	102.5 pcf	7.6	-0.058
Relative Compaction	102.4%	5.7	0.395
Specific Gravity	2.72	0.12	-0.154
Plasticity Index	0.1	0.4	0.392
Liquid Limit	23.8	4.2	0.196
Oregon Air Degradation - II	3.5 in.	4.7	0.319
Oregon Air Degradation - P20	26.4%	9.8	-0.024
Color	1.8	0.4	-0.183
Coefficient of Uniformity	52.6	31.4	0.269
Coefficient of Curvature	0.72	0.56	0.323
Percent Passing 1 1/2"	96.1%	5.6	-0.119
" " 3/4"	88.9%	6.9	-0.117
" " 3/8"	76.2%	7.4	-0.213
" " #4	61.4%	8.6	-0.341
" " #10	50.1%	9.5	-0.325
" " #40	31.1%	8.0	-0.312
" " #200	9.6%	2.8	-0.243

Pit Source Variables

Variable	Mean	Standard Deviation	Correlation with PI
Los Angeles Abrasion	46.7%	10.6	-0.029
Liquid Limit	23.5	3.3	-0.082
Unit Weights, Loose	67.1 pcf	7.5	-0.073
Coefficient of Uniformity	38.1	22.6	-0.071
Coefficient of Curvature	1.60	1.21	-0.127
Percent Passing 1 1/2"	96.1%	2.8	0.328
" " 3/4"	86.0%	6.5	0.310
" " 3/8"	69.0%	9.8	0.286
" " #4	50.5%	12.8	0.247
" " #10	37.1%	13.4	0.252
" " #40	18.5%	8.4	0.090
" " #200	4.6%	2.5	0.095

FIGURES

Figure 1.	Sycan Road, N of Bly, Oregon. Contrast between washboard surface using purple cinders (foreground) and smooth surface using red cinders (background).
Figure 2.	Kirk Road, NE of Chiloquin, Oregon. Rough surface using black, uniformily graded cinders - PI = 2.1.
Figure 3.	Twincheria Road, E of Butte Falls, Oregon. Cinders cemented with iron oxide producing a hard, compact riding surface - PI = 3.1.
Figure 4.	Study Location Map.

Figure 1

Figure 2

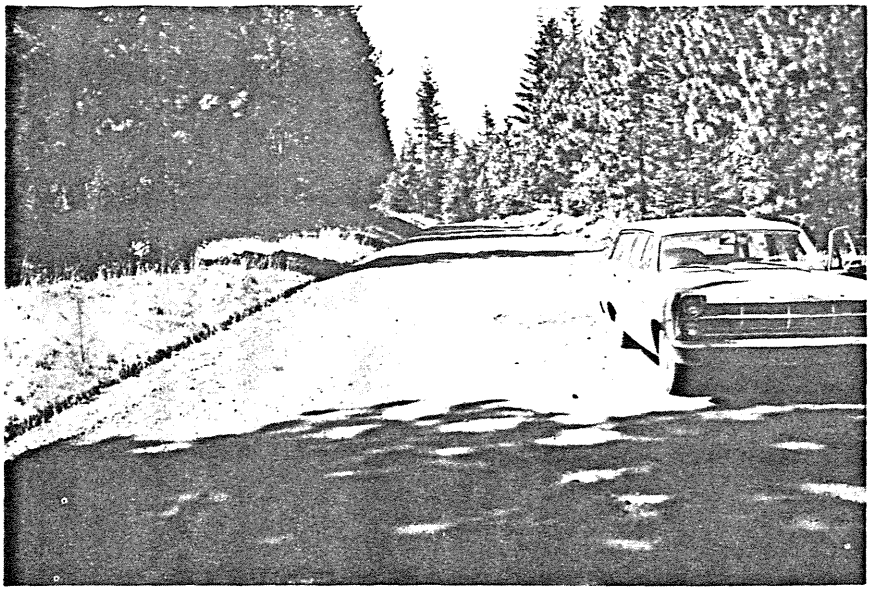
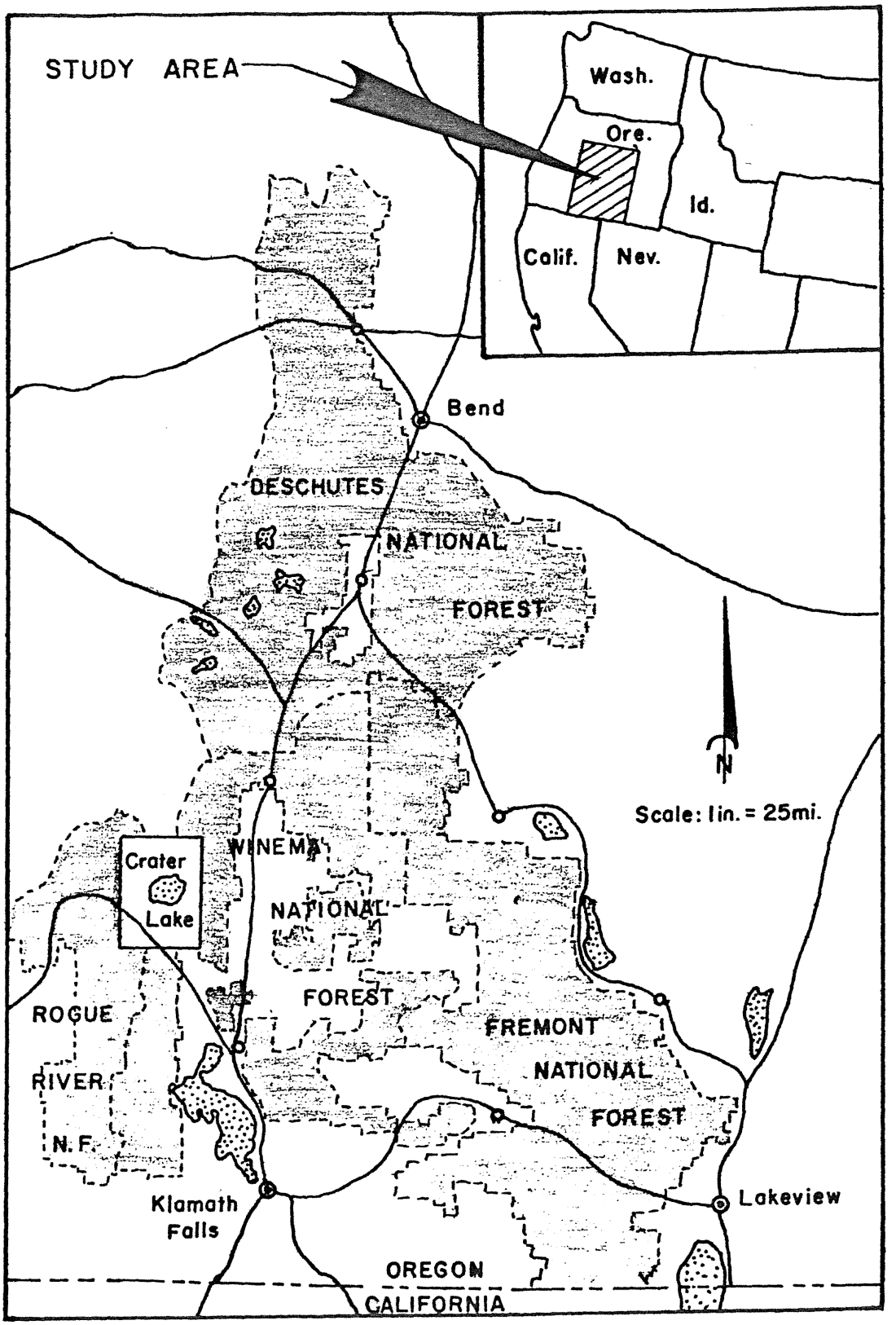


Figure 3

Figure 4


STUDY AREA
Wash.
Ore.
Id.
Calif.
Nev.
Bend
DESCHUTES
NATIONAL
FOREST
N
Scale: 1in. = 25mi.
WINEMA
NATIONAL
FOREST
Crater
Lake
ROGUE
RIVER
N. F.
FREMONT
NATIONAL
FOREST
Klamath
Falls
Lakeview
OREGON
CALIFORNIA

7110

Administrative Study

Winema National Forest

PRELIMINARY REPORT
QUANTITATIVE MEASUREMENT OF DUSTING ON AGGREGATE SURFACE ROADS

By

Eugene A. Wellman
Stephen A. Barraclough

Presented for
THE WINEMA NATIONAL FOREST WORKSHOP
VOLCANIC MATERIALS IN LOW COST
ROAD CONSTRUCTION

October 5, 1970

Submitted Eugene A. Wellman 10/7
Eugene A. Wellman Date

ABSTRACT

Observations and measurements of the amount of dusting produced by 423 vehicles on several aggregate surface roads were accomplished during the summer of 1970. Quantitative dustfall measurement at roadside sampling stations was carried out by A.S.T.M. standard methods. Dust density measurements by means of a photoelectric densitometer specially designed for this purpose were taken on all vehicles. Dust level ratings by means of a 5-member panel were also obtained on the roads studied. Correlation of quantitative dustfall, instrumental opacity measurements and dust rating by panel members is presented.

DUSTFALL MEASUREMENTS ON VARIOUS FOREST ROAD TYPES

Eugene A. Wellman and Stephen A. Barraclough

Introduction:

Concern about the amount of dust produced by recreational and logging traffic on Forest roads within National Forest boundaries led to the initiation of a Measurement Study. Primarily, the purposes of the project were:

(a) To devise a method for quantitative measurement of road dusting.

(b) To correlate dusting and visibility reduction.

(c) To establish a specification for allowable dusting in relation to visibility reduction.

(d) To determine the level of dusting acceptable to travelers in terms of comfort and convenience.

Secondarily, two additional factors were proposed but as yet have received no study. These are:

(a) Aesthetic effects of dusting on roadside facilities users.

(b) Ecological effects of road dust on adjacent vegetation.

A number of variables are recognized as being significant in the results obtained. Some, such as temperature and relative humidity, were minimal in their effect during the period of data collection. Wind

direction and velocity effects were minimized by the design characteristics of the sampling site (Fig. I). Precipitation, while potentially a significant variable, was absent during the study period. Terrain and Forest cover effects on dust drift were of some significance but, by careful selection of sampling stations, were considered to be equivalent, one station to another. Road surface characteristics, traffic speed and distribution of traffic types were all tabulated individually by direct observation.

Methods

1. Quantitative measurement of settleable dust was made, as outlined in A.S.T.M. Standard D-1739-62 (Reapproved 1967), American Society for Testing Materials (Fig 2). Dust samples were collected only during periods of traffic observation. Quantitation of the dust collection was accomplished by filtration, drying to constant weight, and final weighing.

2. Temperature measurement at each sampling site was taken with both wet and dry bulb thermometers to enable the relative humidity to be determined.

3. Wind speed was measured by means of a portable anemometer. Direction was determined by compass.

4. Visibility measurement was accomplished by means of a portable densitometer designed and fabricated especially for the project (Fig 3). Transillumination of the dust cloud generated by vehicular

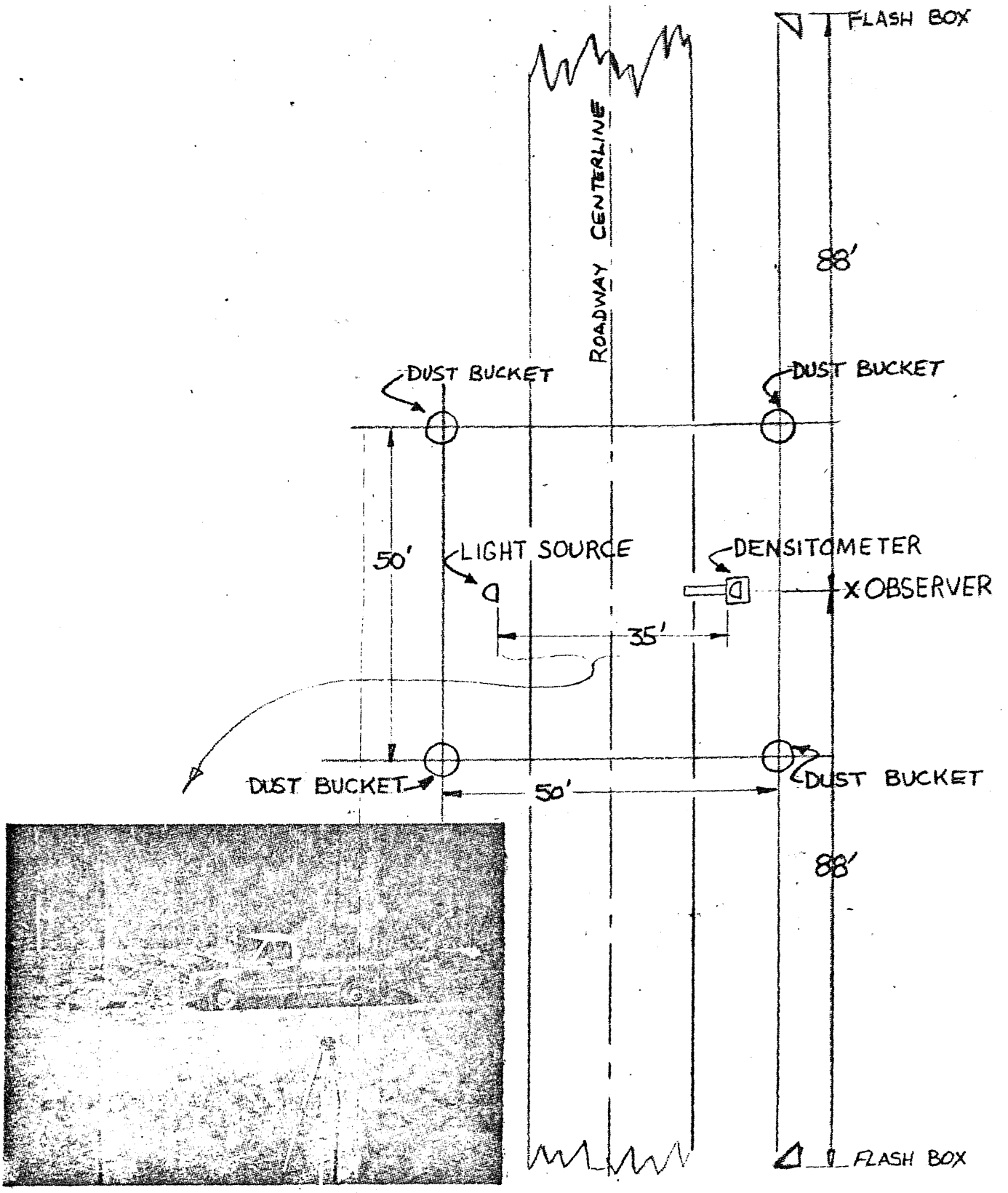


FIGURE 1. STANDARD SAMPLING SITE FOR DUSTFALL MEASUREMENT ON AGGREGATE SURFACE ROADS.

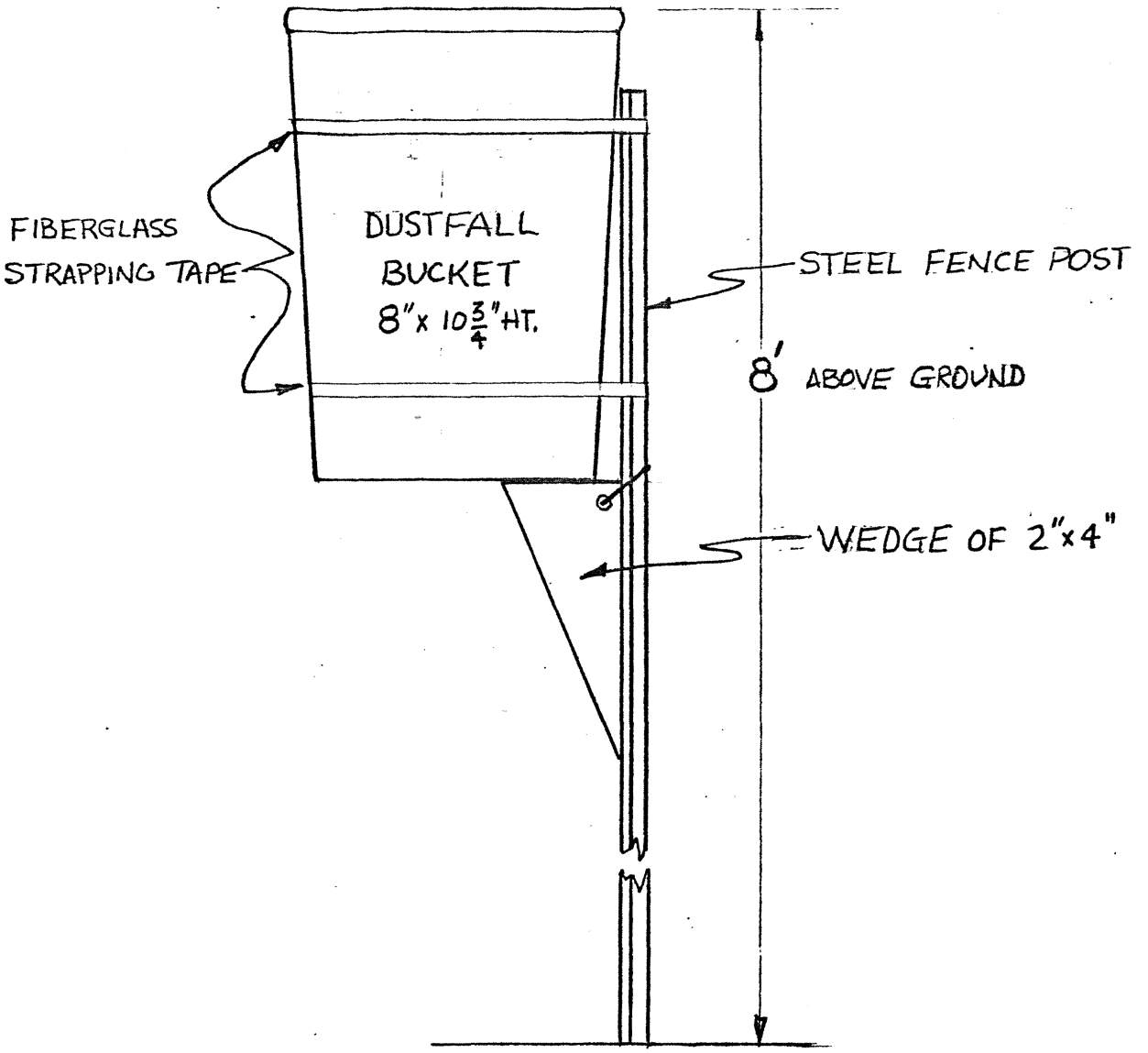


FIGURE 2. DUSTFALL SAMPLING BUCKET AND STANDARD.

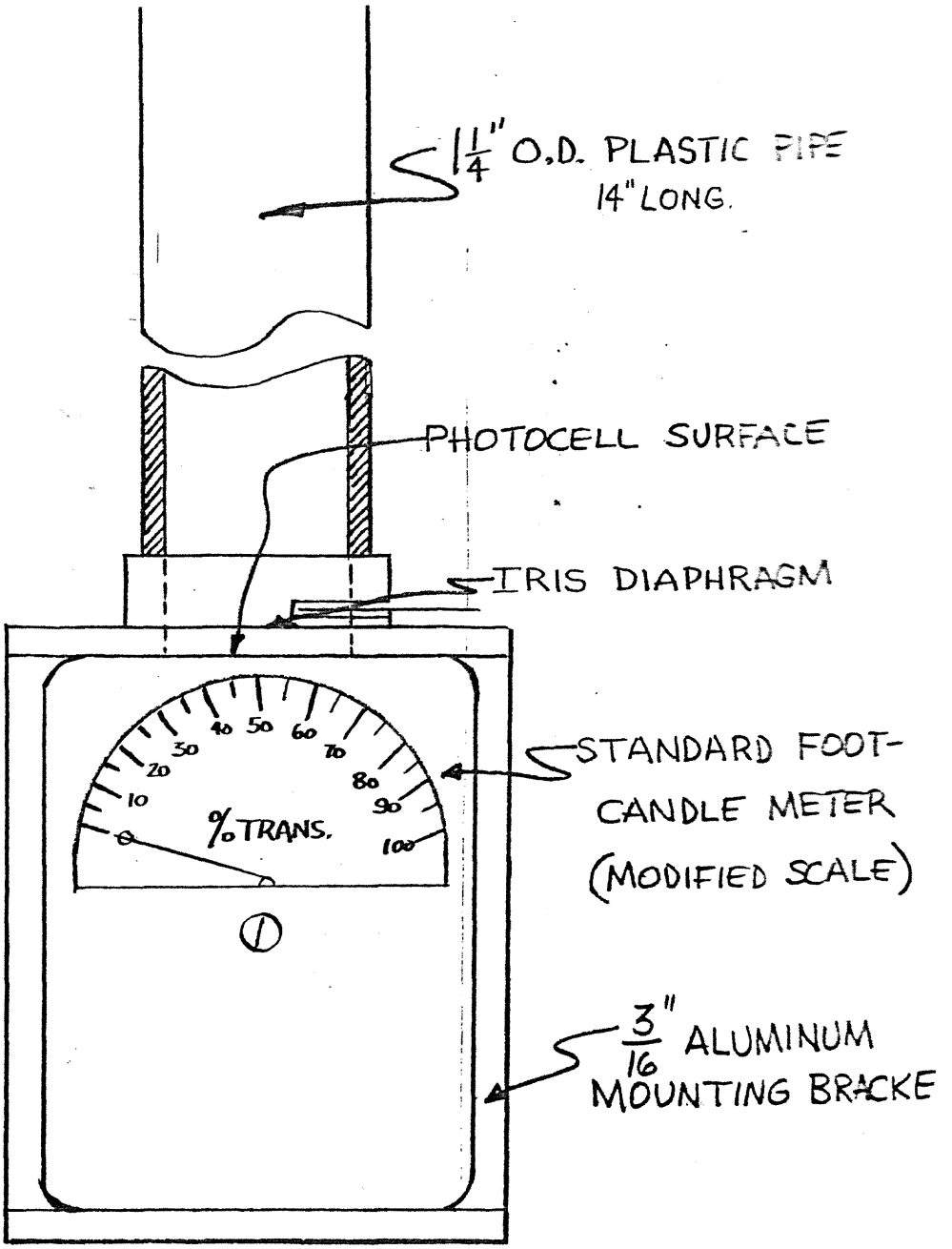


FIGURE 3. PHOTOELECTRIC DENSITOMETER USED FOR EQUIVALENT OPACITY MEASUREMENT.

traffic was accomplished by the use of a 12V 150W aircraft landing light attached to the battery of the vehicle used for transportation. All measurements were initially made in terms of percent light transmission through the dust cloud. On reduction of data to graphic form, conversion to percent Equivalent Opacity (100 - %T = % Equivalent Opacity) was felt to provide more meaningful expression of results because of the established usage of the Equivalent Opacity concept in air pollution abatement regulations and standards.

5. Vehicular speed through the sampling site was determined by means of timed transit between the meter location and flash boxes located 88' on either side of the meter (Fig 1).

6. Sites of sampling stations were selected to provide as nearly as possible the same forest cover, terrain, and exposure characteristics. As sample collection was only performed during periods of observation of traffic, differences in traffic frequency were not felt to be significant. Each site was maintained for sampling throughout the observation period until a total of 60-75 vehicles had been classified, and speed and opacity measurements made.

7. Visibility obstruction and sight distance measurements were accomplished by the use of visibility range markers and slow motion cinematography (Fig 4). Analysis of motion picture film footage will, when completed, be the subject for a subsequent report.

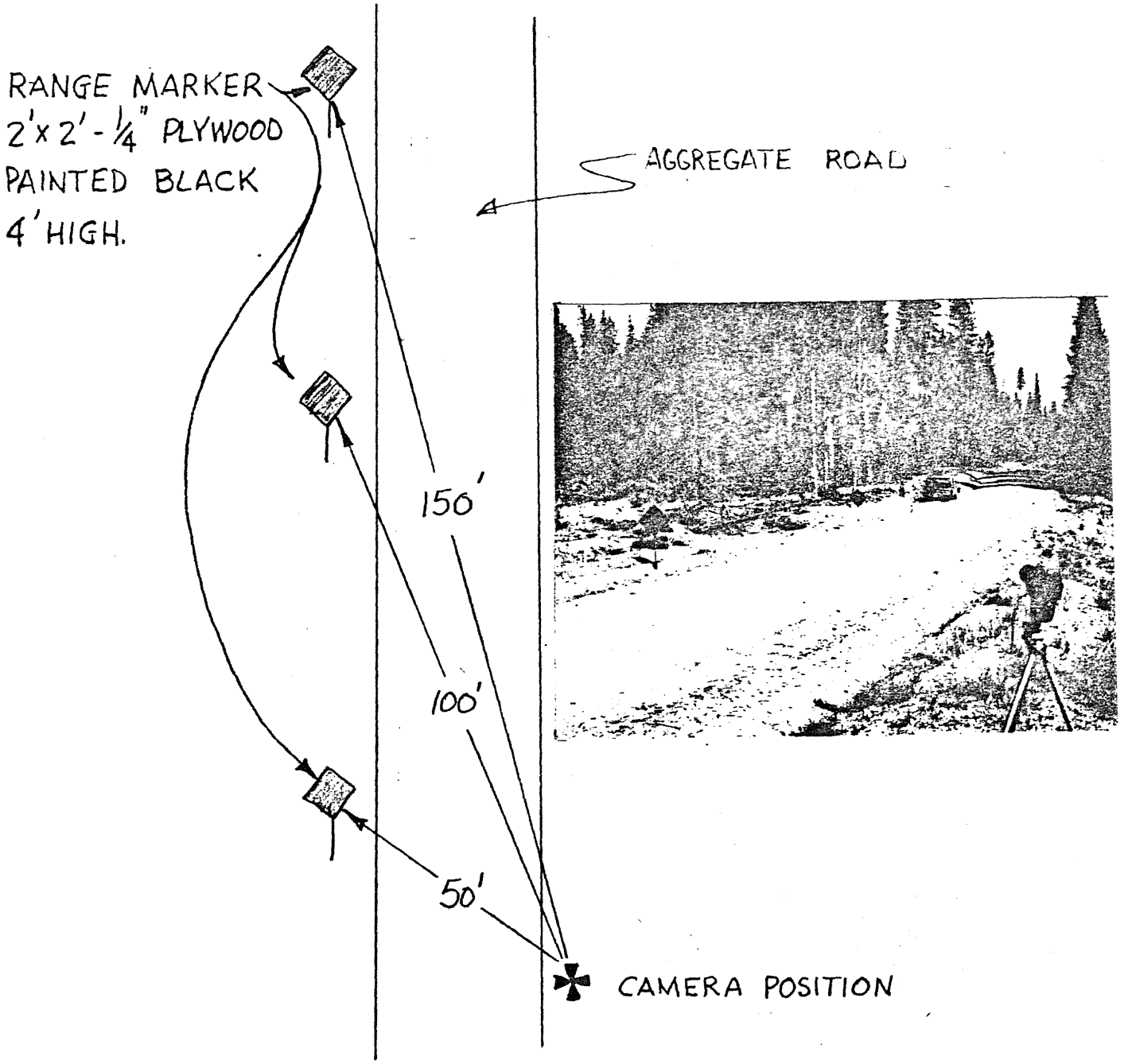


FIGURE 4. VISIBILITY MEASUREMENT STATION.

8. Control stations for background dustfall measurements were established at Chiloquin District Ranger Station, Chemult District Ranger Station and Yamsay Guard Station. Collection of dustfall was made through July and August 1970.

Results:

Quantitative dustfall data is summarized in Table I(Fig 5). Values were expressed in terms of dustfall weight per square meter per month to relate to standard fallout sample data as used in general air pollution statistics. More meaningful expression of dust weight can be found in Table 2 (Figure 6), (Figure 6A), which indicates dust quantity in terms of weight per vehicle. Total traffic numbers and distribution consisted of 423 vehicles, 88.4% trucks, 11.6% light vehicles, upon which collection data was based and opacity measurements obtained.

In conjunction with dustfall collection, observations on all vehicles included speed and dust cloud density (Equivalent Opacity). Summarization of all readings of opacity and speed relationships are presented on Figures 7-12. In all cases, dusting quantity appears to have a definite relationship to vehicular weight and speed. Composite Graph Figure 12 indicates the relative difference between loaded and unloaded trucks on two roads studied. Lack of log haul traffic on pumice roads made it impossible to compare pumice dust levels with the other

CONTROL STATIONS (July & August)

Chiloquin District Ranger Station	0.905	$g/M^2/mo.$
Chemult District Ranger Station	0.545	$g/M^2/mo.$
Yamsay Guard Station	0.498	$g/M^2/mo.$

SAMPLING STATIONS

#1. Road #3852	189.5	$g/M^2/mo.$
#2. Road #3800	259	$g/M^2/mo.$
	189.5	$g/M^2/mo.$
	204	$g/M^2/mo.$
#3. Road #35013	84	$g/M^2/mo.$*
	131	$g/M^2/mo.$

* Dust abatement by means of light watering.

Figure 5. Table 1: Quantitative dustfall from control stations and sampling sites.

QUANTITATIVE DUSTFALL DATA

Station	Road No.	Total Wt.	Total Vehicles	Ave. wt./M^2/vehicle
#1.	3852	$2.82g/M^2$	70	40 mg.
#2.	3800	$3.86g/M^2$	75	44.5mg
		$2.82g/M^2$	70	
		$3.02g/M^2$	72	
#3.	35013	$1.25g/M^2$	63	23.7mg
		$1.95g/M^2$	73	

Figure 6. Table 2: Dustfall Data - Traffic Relationships. Road #3852 Single lane with turnouts surfaced with pit run cinder. Road #3800 two lane surfaced with crushed rock. Road #35013 single lane with turnouts surfaced with pit run aggregate.

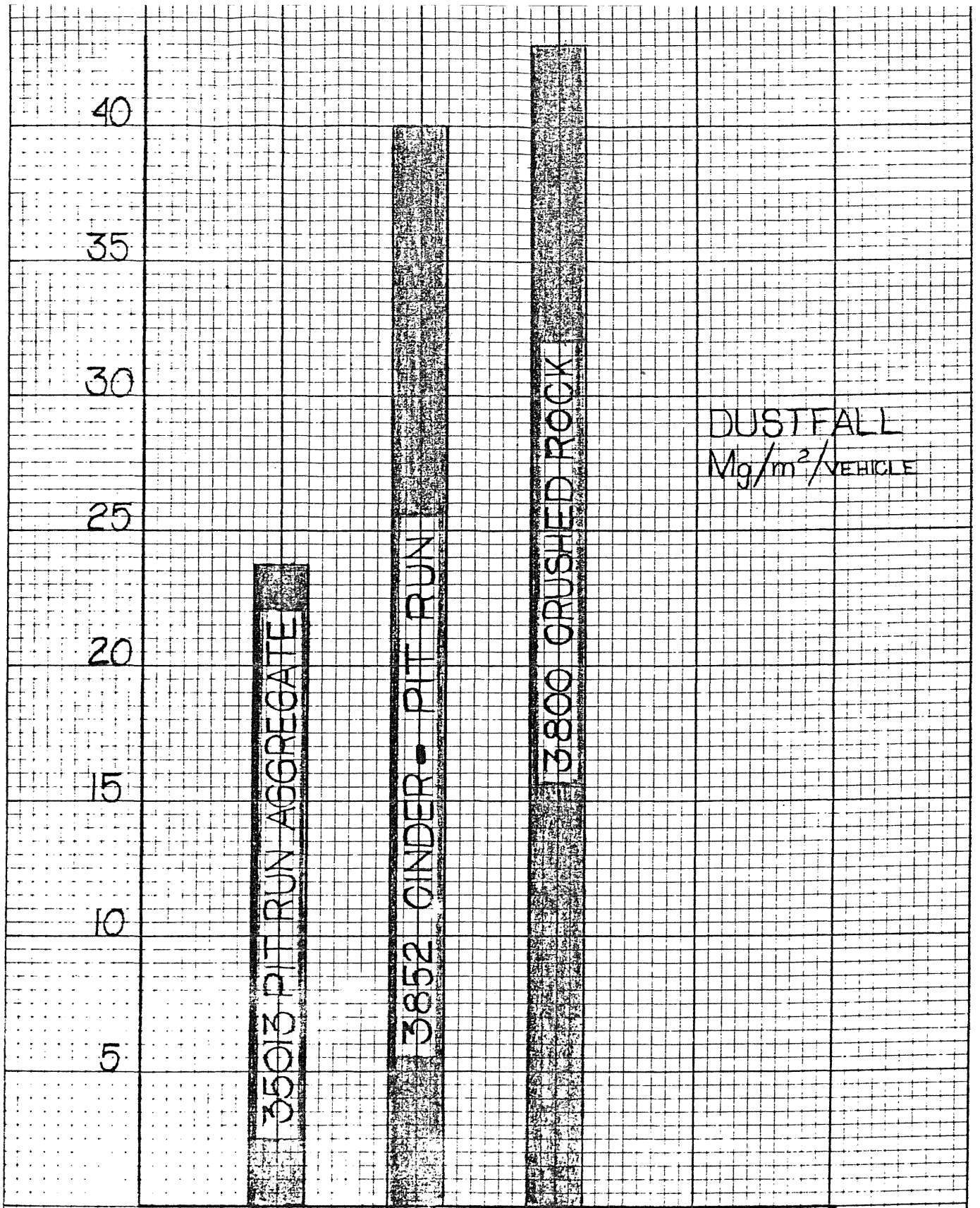


FIGURE 6A. QUANTITATIVE DUSTFALL WEIGHT per SQUARE METER per VEHICLE

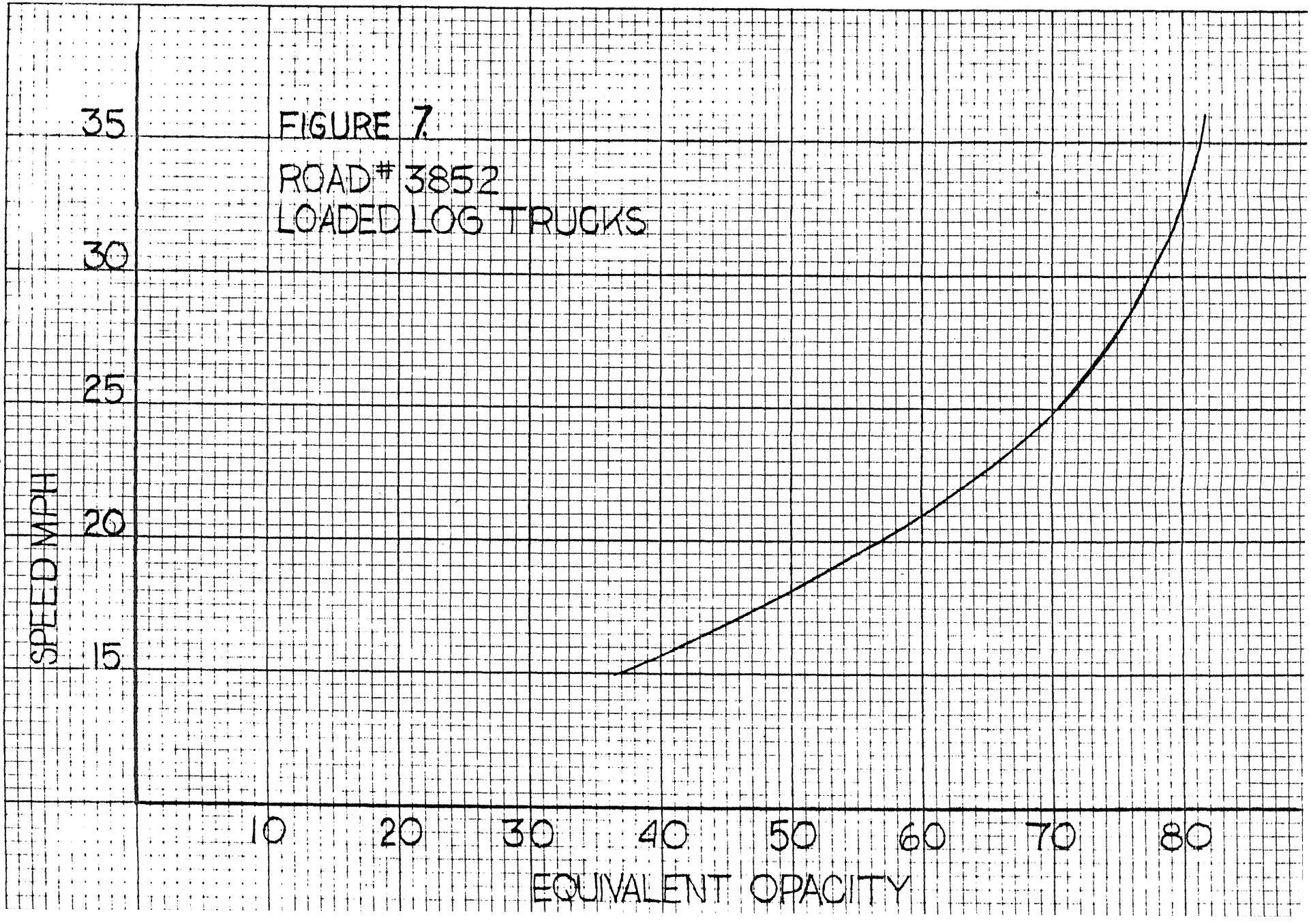
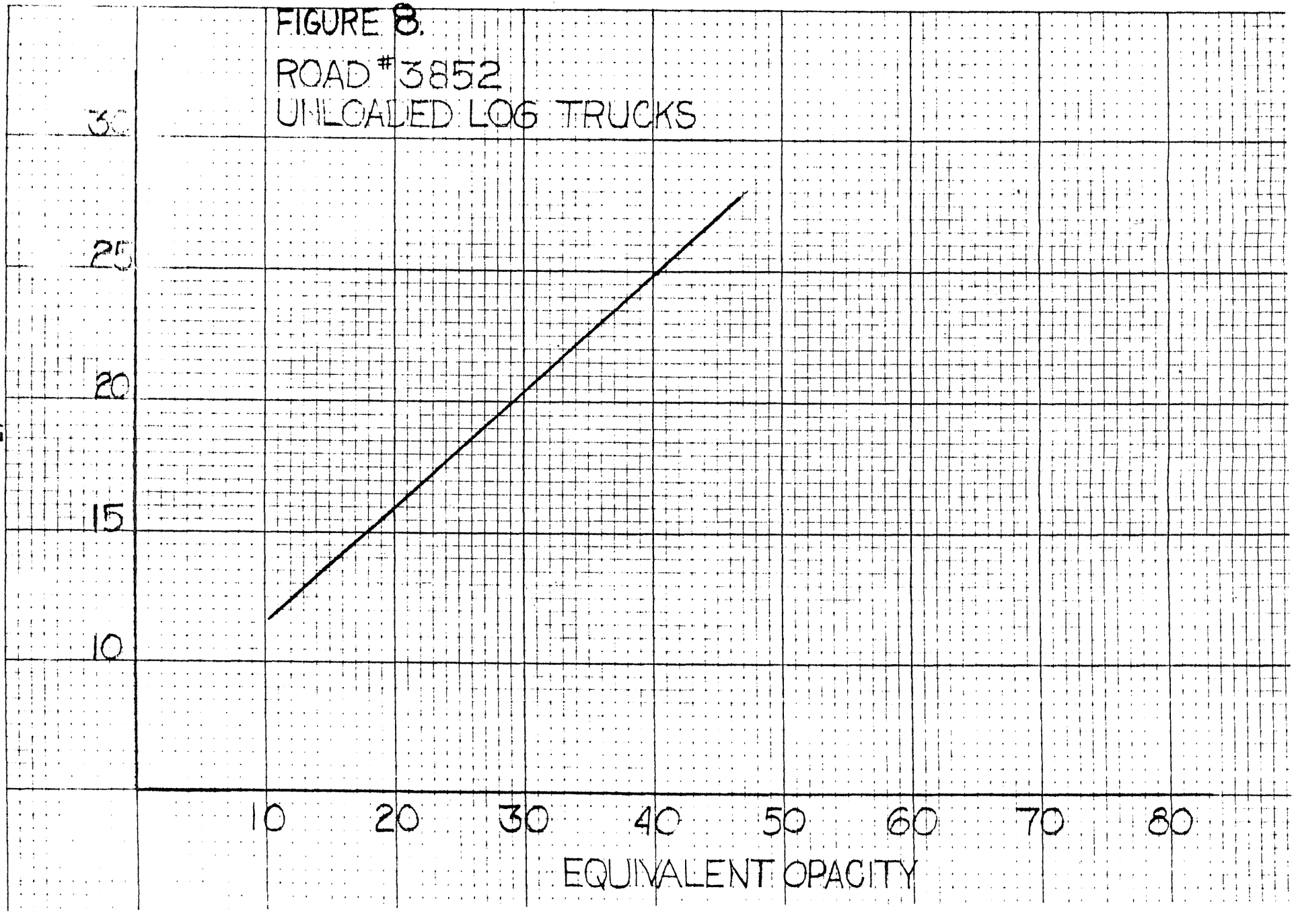


FIGURE 7.
ROAD # 3852
LOADED LOG TRUCKS
35
30
25
20
15
SPEED MPH
10
20
30
40
50
60
70
80
EQUIVALENT OPACITY

FIGURE 8.


ROAD # 3852
UNLOADED LOG TRUCKS
30
25
20
15
10
10
20
30
40
50
60
70
80
EQUIVALENT OPACITY

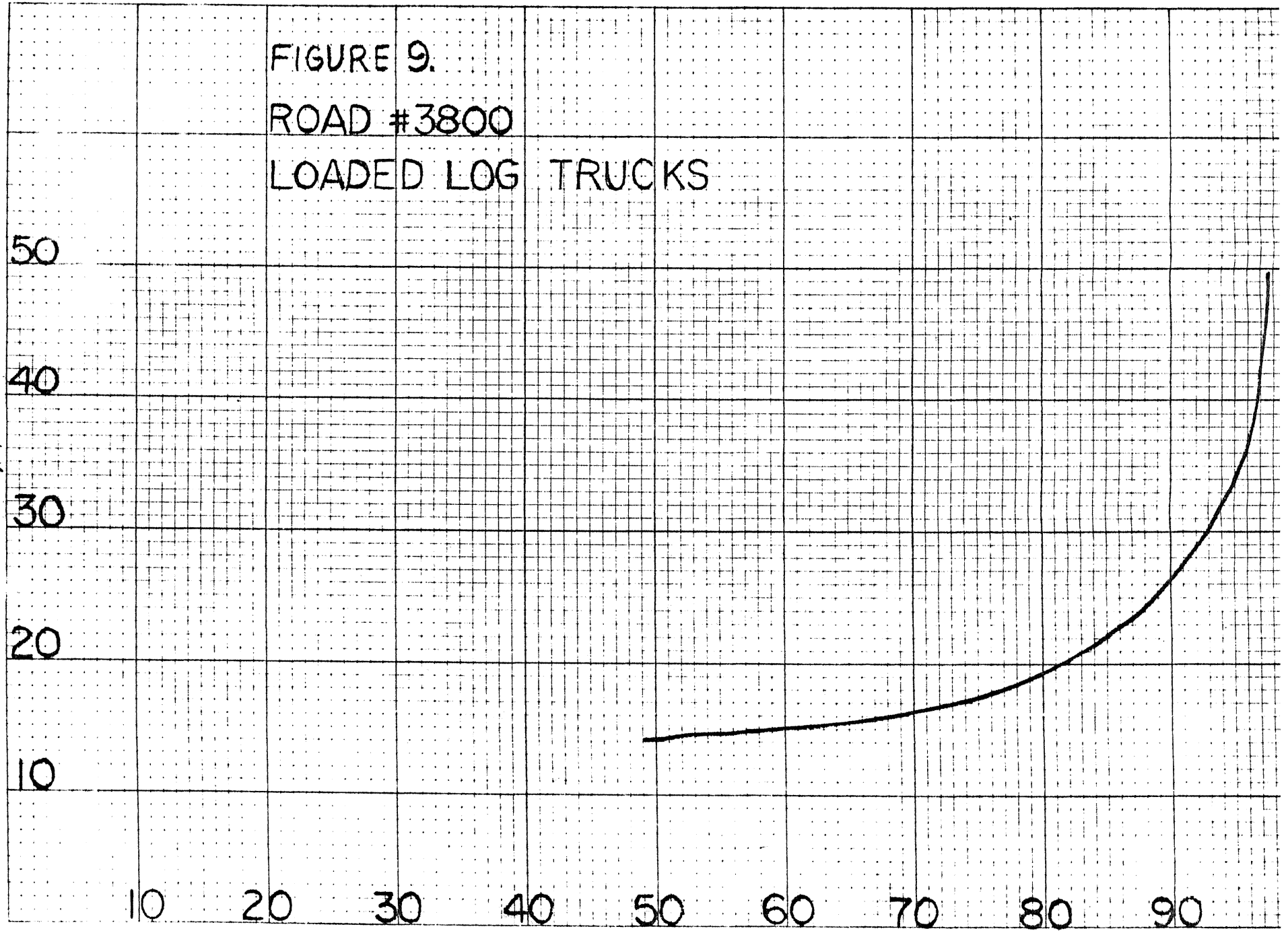


FIGURE 9.
ROAD #3800
LOADED LOG TRUCKS
50
40
30
20
10
10
20
30
40
50
60
70
80
90

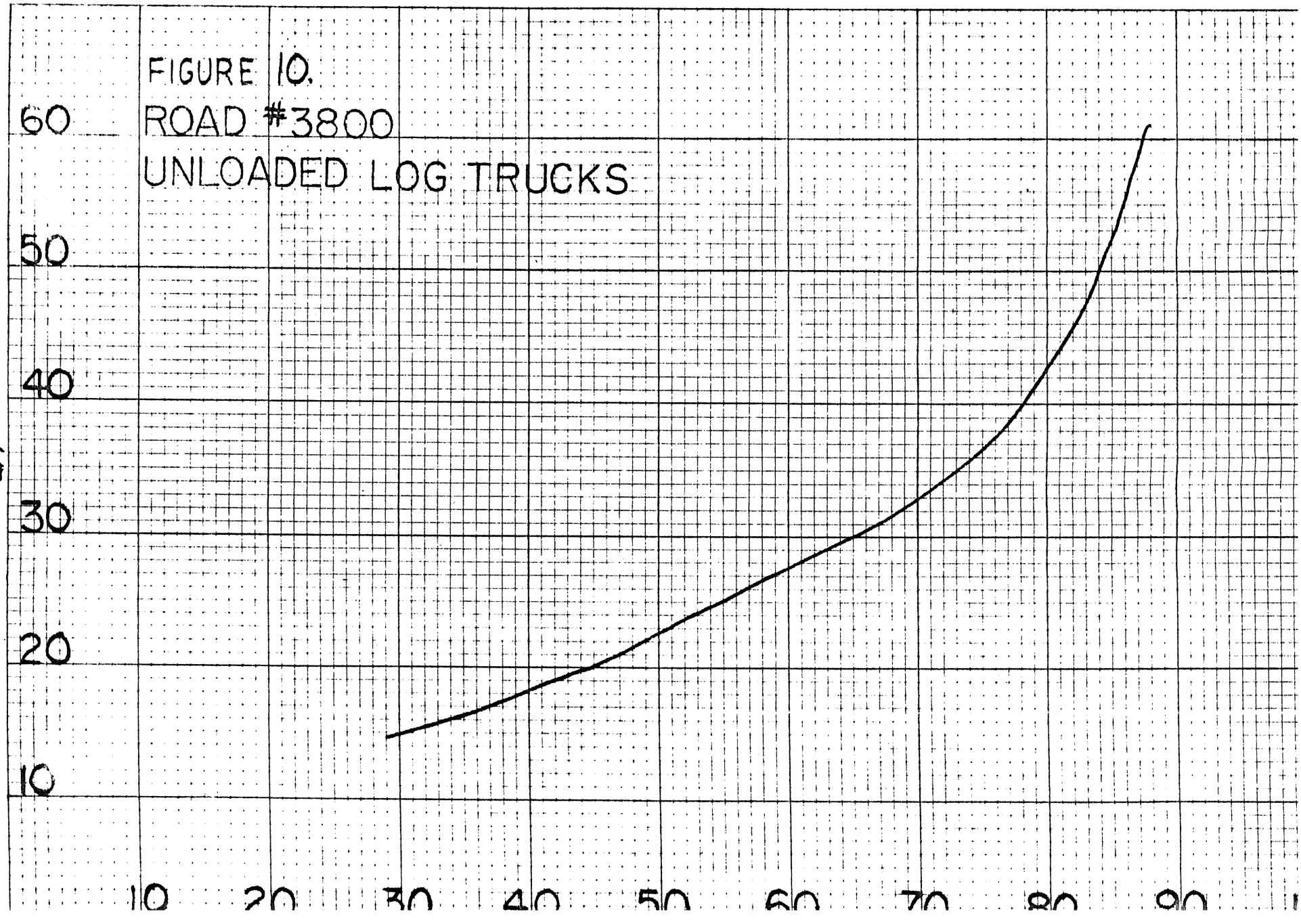


FIGURE 10.
ROAD #3800
UNLOADED LOG TRUCKS
60
50
40
30
20
10
10
20
30
40
50
60
70
80
90

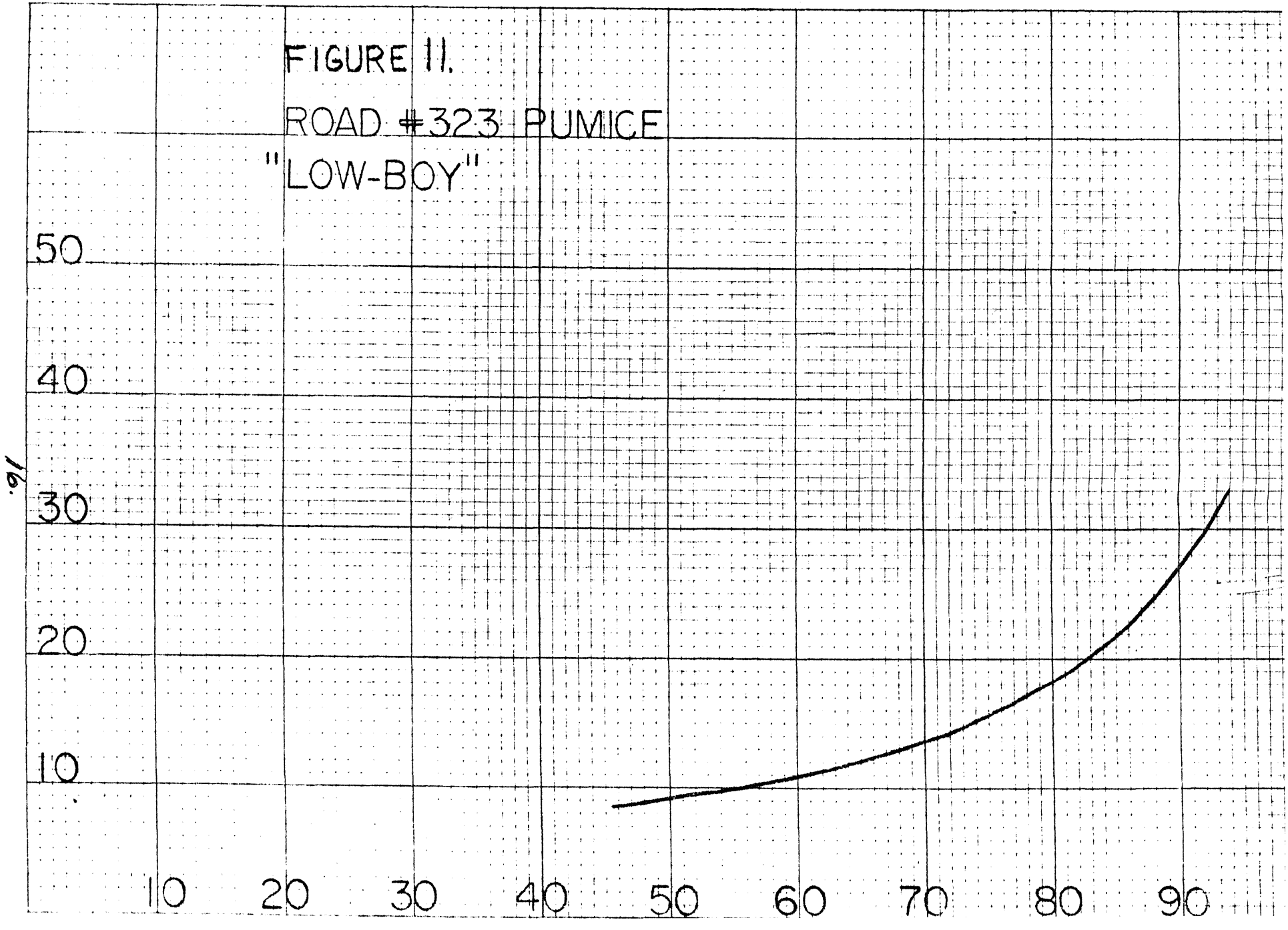
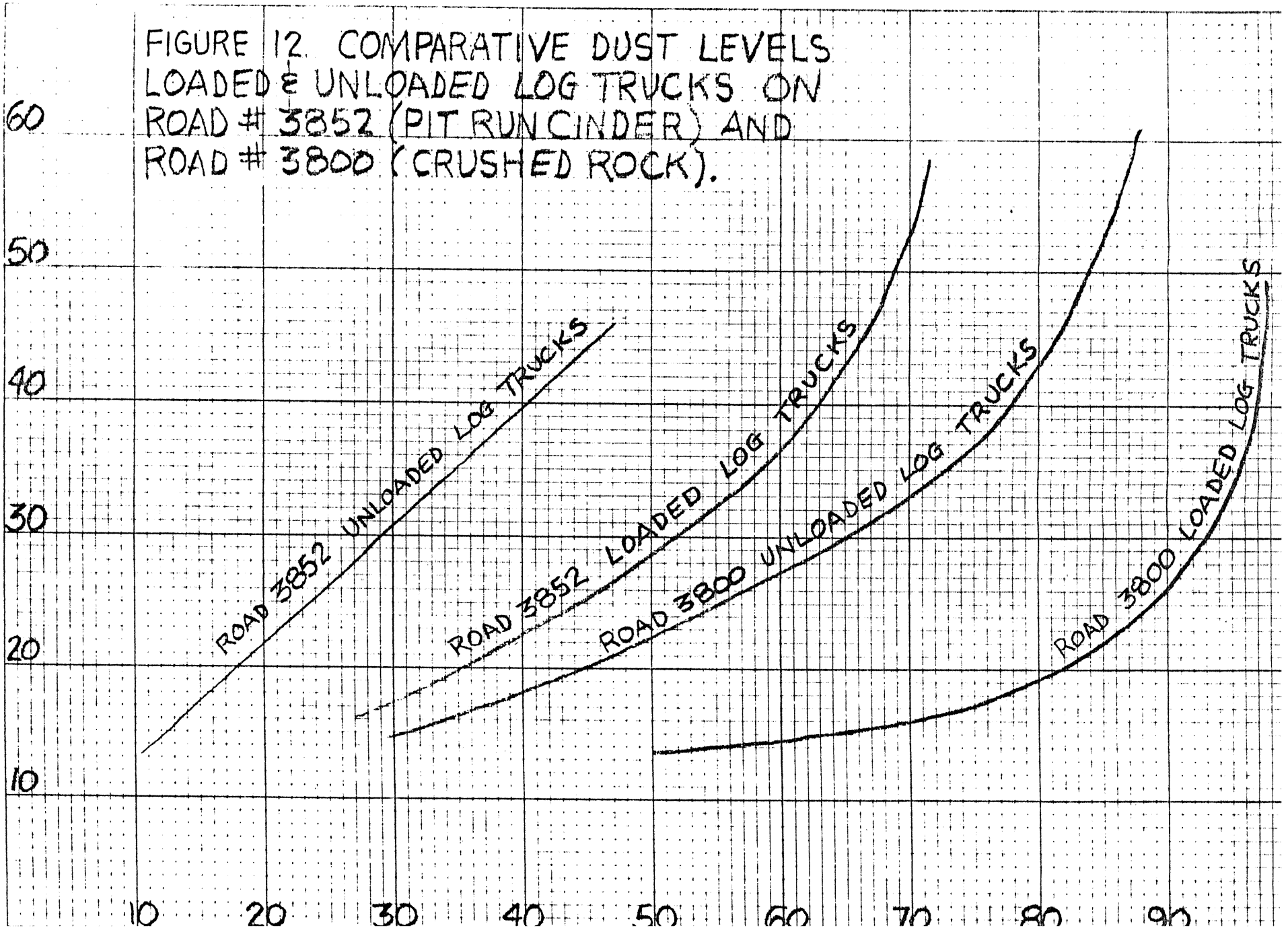


FIGURE 11.
ROAD #323 PUMICE
"LOW-BOY"
50
40
30
20
10
lb.
10
20
30
40
50
60
70
80
90

FIGURE 12. COMPARATIVE DUST LEVELS LOADED & UNLOADED LOG TRUCKS ON ROAD # 3852 (PIT RUN CINDER) AND ROAD # 3800 (CRUSHED ROCK).



surfaces studied; however, controlled runs with a U.S.F.S. "low-boy" truck provided some data (Figure 11).

When average Equivalent Opacity for all vehicles represented in the quantitative samples is plotted against the dustfall weight per square meter, per vehicle, an excellent correlation appears to be present (Figure 13). Further research on other sampling sites is necessary to determine whether the direct relationship of opacity to dust quantity can be further verified.

Should this occur, the ability to equate average equivalent opacity and quantitative dustfall will provide a rapid evaluation tool for management of road dusting problems. Furthermore, greater coverage of haul routes and evaluation of dust abatement programs would be possible in a given period of time. Evaluation of results could be made directly at the site without the necessity of tedious laboratory analysis of dust bucket collections.

Evaluation of Dust Level Acceptability by Means of Rating Panel

Following a preliminary trial of the rating concept for dust level acceptability with three members of the Engineering staff, a full five-member panel was selected. Three were Engineering staff personnel and two secretarial staff. Rating instructions were printed and given each member of the panel, along with several copies of the Rating Form (Figure 14). Panel members were asked to observe the

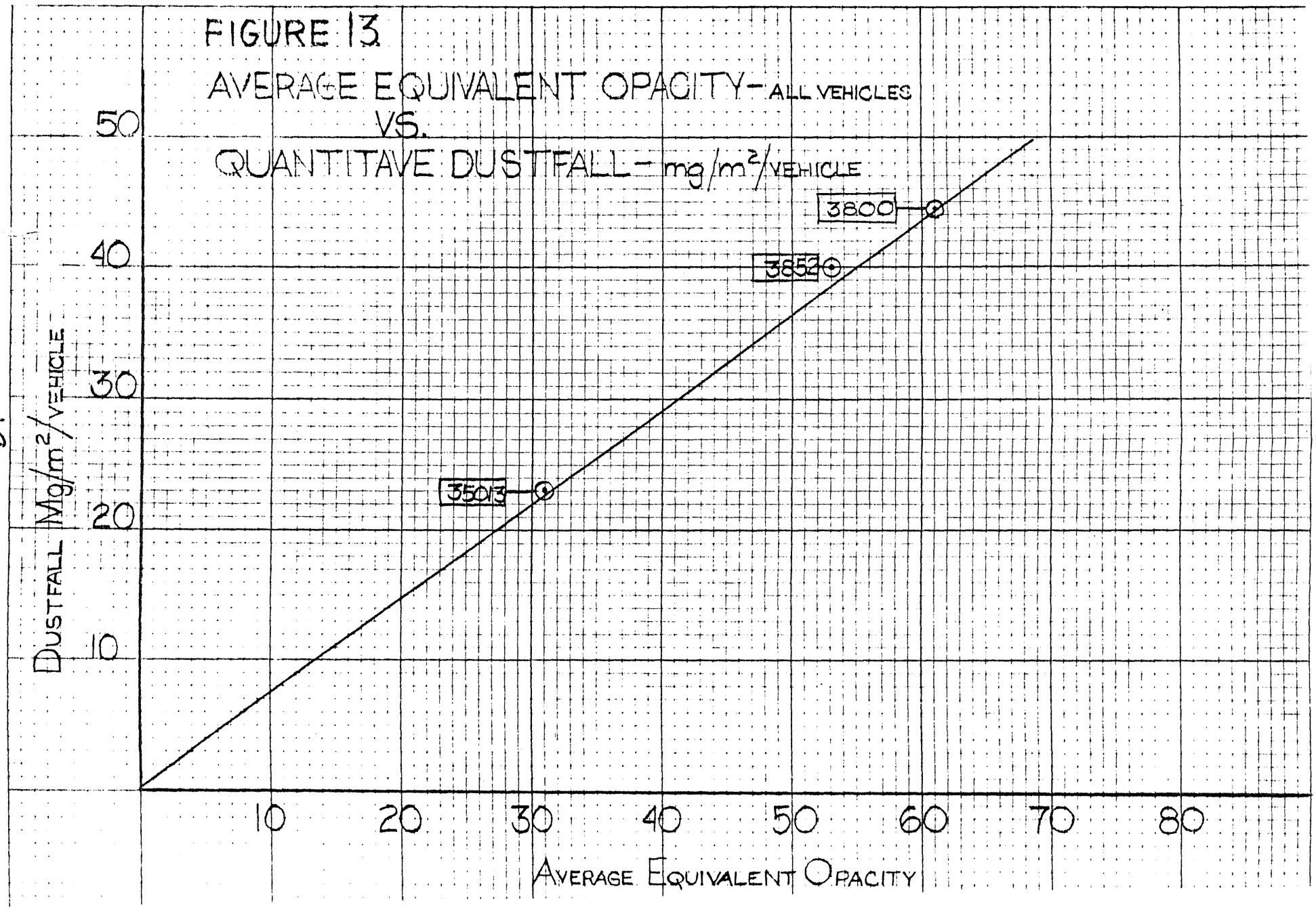


FIGURE 13.
AVERAGE EQUIVALENT OPACITY - ALL VEHICLES
VS.
QUANTITAVE DUSTFALL - mg/m²/VEHICLE
3800
3852
3501.3
DUSTFALL Mg/m²/VEHICLE
50
40
30
20
10
10
20
30
40
50
60
70
80
AVERAGE EQUIVALENT OPACITY

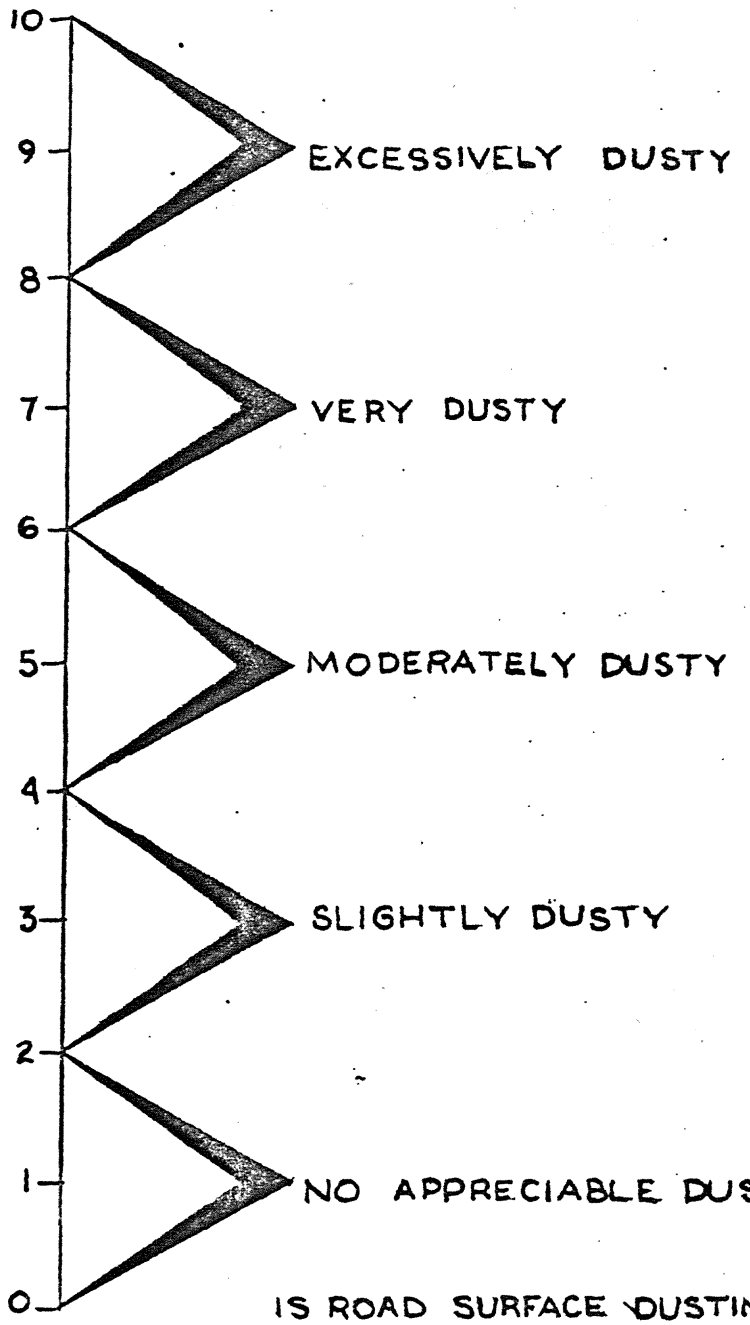
DUST LEVEL ACCEPTABILITY RATING FORM

RATER: _____

ROAD#: _____

SURFACE: _____

DATE: _____



IS ROAD SURFACE DUSTING ACCEPTABLE IN TERMS OF COMFORT & CONVENIENCE?

YES ——— ☐

NO ——— ☐

UNDECIDED - ☐

COMMENTS: _____

_____

_____

dust levels generated by traffic with reference to density, persistence, height and visibility impairment, and to then evaluate the dust level on the Rating Form provided. Finally, the acceptability question was to be answered on the basis of "Yes", "No", or "Undecided".

Five vehicles were observed on each of three different sections of road chosen to provide three different dusting levels. Each of the five panel members rated each vehicle without consultation. Equivalent Opacity measurements were also made on each vehicle rated by the panel. Correlation of assigned dust rating values and Equivalent Opacity measurements are found in Figure 15. On the cinder section of Road 3800, the average assigned dust rating was 3.31 units with a standard deviation of $\pm$0.46 D.R. units. Probability of acceptance was 100% at an average opacity of 16%. On the aggregate surface of Road 34013, an average of 4.45 units was obtained, with a standard deviation of $\pm$0.44 D.R. units. Probability of acceptance on this section was 20%, probability of rejection 40%, with 40% undecided. Equivalent Opacity averaged 36%. On the crushed rock section of Road 3800 (Site #2), the average dust rating of the panel was 7.20 with a standard deviation of $\pm$0.284 D.R. units. Average dust opacity produced by the vehicles rated was 65%. At this level, the panel all classified the dust level as unacceptable.

DR
AVERAGE EQUIV. OPACITY
10
20
30
40
50
60
70
80
90
1
2
3
4
5
6
7
8
9
10
ROAD # 3800 - CINDER
ROAD # 3413 - AGGREGATE
ROAD # 3800 - CRUSHED ROCK
3.31 ± 0.46
4.45 ± 0.44
7.2 ± 0.284
P_A = 100%
P_A = 20%
P_A = 40%
P_A = 40%
P_A = 0

Summary

In summary, the data collected, while obviously not complete, provides a basis for several observations --

First; the degree of dusting is a function of vehicle speed, gross weight, number of wheels and the shape of the load, which dictates the amount of turbulence produced.

Second: We have found some striking correlations between the various evaluation and measurement procedures utilized. Dust quantitation is possible by dust bucket collection, densitometry and also, indirectly by means of a rating panel. The three methods demonstrate good correlation one to the other.

What, then, are acceptable levels of dusting? It appears from the limit data collected to date that a panel of observers will accept dusting up to about 35% Equivalent Opacity. This represents a dust quantity of approximately 25 mg/M^2/vehicle.

Correlation of dustfall, Equivalent Opacity and visibility obstruction will be presented in the final report in conjunction with statistical analysis of speed vs. opacity observations.

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5. Dust Control in the Theater of Operations. Corps of Army Engineers. Waterways Experiment Station Vicksburg, Miss.

USE OF PUMICE

AS A

ROAD CONSTRUCTION MATERIAL

BY

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September 1970

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John W. Lund Date

Submitted Larry G. Hendrickson 8 Sept.
Larry G. Hendrickson Date

ABSTRACT

The study was undertaken to investigate the engineering characteristics of volcanic pumice and how the material can best be utilized for forest access road construction. The use of pumice was investigated in an untreated condition and treated with stabilizing agents.

A literature review and local field investigation in Oregon were made to determine current use and construction practice with pumice. Based on this information, laboratory testing was undertaken to determine what type of stabilization appeared to be most beneficial for pumice and to determine the optimum percentage of additive.

A test road was selected on the Winema National Forest and the pumice sampled for laboratory testing. Hydrated lime, type II cement, clay from a local cinder pit, bituminous stabilizer 120 (BS-120) and SS-k emulsion treated samples were tested in unconfined compression, as no other test method appeared feasible to evaluate the relative merits of the various stabilizers.

Based on the laboratory test results, six test sections were incorporated in the test road. These included six-inch deep road mix sections of cement, lime, cinder clay and BS-120 at 5%, 5%, 30% and 15% respectively by weight. Half of the lime and cement treated sections were sealed with 0.3 gal/sy of BS-120. In addition, two penetration sections using BS-120 at 1.1 gal/sy and 1.6 gal/sy were constructed.

Over a period of 8 months, the clay and lime treated sections appeared to perform the best. The cement performed almost as well; however, the asphaltic sections failed in most cases due to inadequate curing. In all cases the treated sections performed better than the untreated pumice.

A thorough investigation of compaction requirements and procedures was not attempted due to the lack of compaction equipment at the time of the test road construction. However, based on past experience, it is recommended that relative density be used instead of relative compaction for field control.

Continued observation and testing will be carried out on the test road during the coming summer.

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STATEMENT OF PURPOSE

The purpose of this study is to determine the engineering characteristics of volcanic pumice and how the material can best be utilized for forest access road construction. The two main phases of study are concerned with the use of pumice in an untreated condition and, secondly, the use of stabilizing agents in pumice. The use of the untreated material concerns itself primarily with construction control techniques, especially as this applies to compaction control.

Preliminary observations indicate that pumice has above average strength and bearing capacity characteristics when used as base and subgrade material, but abrades and dusts badly when used as a wearing surface. As a result, pumice is normally not used as a wearing course for high traffic volume roads. Being able to determine economical methods of improving the properties of pumice for use as a surface course would be extremely beneficial, as much of central Oregon is covered with a mantle of pumice.

BACKGROUND INFORMATION

Pumice is of pyroclastic origin, being ejected from volcanic vents. The term pumice is employed very loosely and can include a wide variety of cellular glassy rocks of volcanic origin (Figure 1). The term Pumice should be applied to rocks that are the light-colored ejecta from acidic and intermediate magmas and consist of pumiceous glasses that are markedly cellular, light enough to float on water and larger than 4 mm. Uncemented and loosely

cemented glassy pyroclastic debris consisting of fragments less than 4 mm in diameter are referred to as pumicite or volcanic ash (1).

Pumice deposits are of three basic types that are of interest to engineers (1):

1. Subaerial - those deposited on dry land. These are characterized by a lack of well-defined bedding and sorting, and a general lack of the finer fraction or pumicite. The pumice fragments are angular and often have other rock fragments mixed throughout the deposit (Figure 2).
2. Subaqueous - those deposited in standing or running water. One of the most distinctive characteristics of this deposit is an inverted graded bedding in which there is an increase in size of pumice particle from the bottom to the top of an individual bed. Another feature is the presence of layers of gravel, sand, silt and clay that alternate with layers of pumiceous material (Figure 3).
3. Nuee Ardente or "glowing cloud" deposits due to an avalanche of a violently expanding cloud of gas and ash descending down the slopes of a vent, often with speeds up to 100 mph. These deposits are characterized by a complete lack of sorting with particles ranging in size from ash to blocks. These deposits are more compacted than other types due to the partial fusion produced by the high temperatures (Figure 4).

Pumice has a true hardness of 5.5 to 6 as applied to the glassy material in the individual cell walls. The apparent hardness may be as low as 2 or 3 when applied to the whole cellular structure (2). The low apparent hardness is the main reason for severe dusting and degradation associated with the material.

The true specific gravity of pumice particles ranges from 2.3 to 2.8 with an average of 2.6. Bulk specific gravities are generally less than 1.0 with values from 0.5 to 0.9. The resultant porosity would then be approximately 70 per cent (3). Oven drying or grinding a sample prior to specific gravity determinations have an effect on the final results. This is due to the capillary absorption of moisture over a long period of time (4). The high porosity of pumice resulting from the frothing during formation has a profound influence on other physical and chemical properties.

OREGON PUMICE DEPOSITS

Two of the more conspicuous pumice deposits in Oregon are the Mazama and Newberry deposits. These deposits are located in south central Oregon east of the Cascade Crest, with ages of 7000 and 2000 years respectively. The Mazama deposit is a dacite pumice and the Newberry a rhyolite pumice. Both deposits consist of coarse particles (sand and gravel size), whereas other central Oregon deposits are generally finer textured (silt and sand size). (3). In addition to the Mazama

and Newberry pumice deposits there are other widespread deposits of unknown age and origin occurring in the Cascade Mountains and throughout central and eastern Oregon. (3).

The pumice from Mount Mazama (now Crater Lake) fell over Central and eastern Oregon and eastern Washington in two basic forms; first as an airborn shower that fell north and east of the area and as ash farther north in Oregon, Washington and finally Canada; and, secondly, as "glowing avalanche" in the vicinity of Crater Lake. This latter deposit exists principally west to Klamath Marsh, north to Chemult and the headwaters of the North Umpqua River, and west to the Rogue River where the deposits are several hundred feet thick. Forest Service road construction in each of these two types differs due to the physical characteristics of the deposits. These two methods are described in the Field Investigation section.

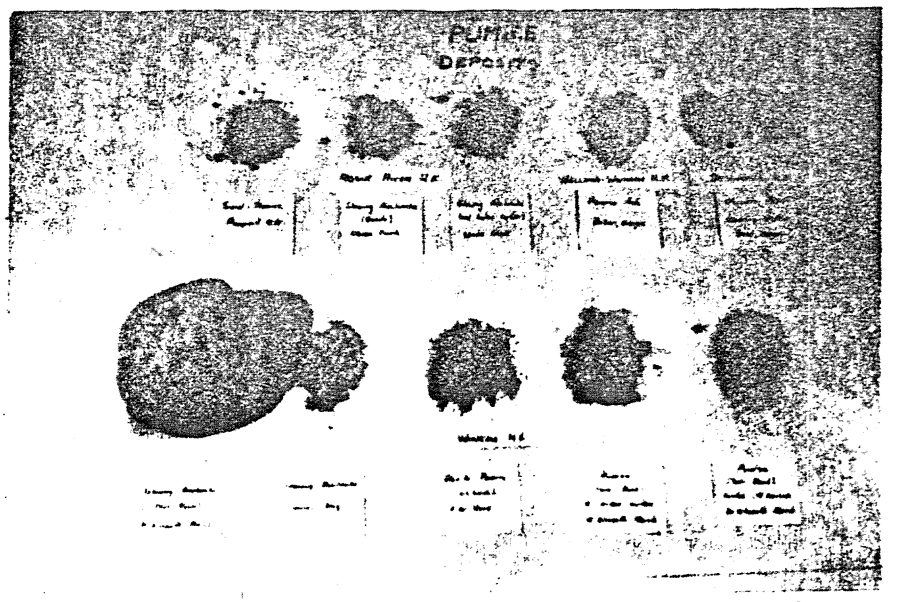

FIGURE 1. Example of Pumice Types

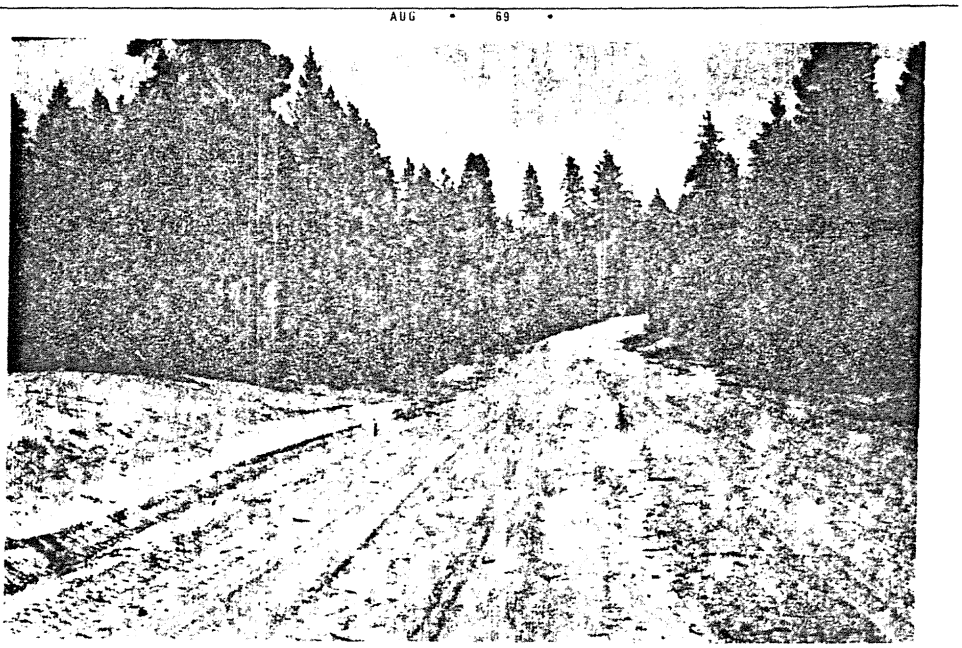

FIGURE 2. Mazama Pumice (subaerial) on East-West Road, East of Chiloquin, Winema N. F.

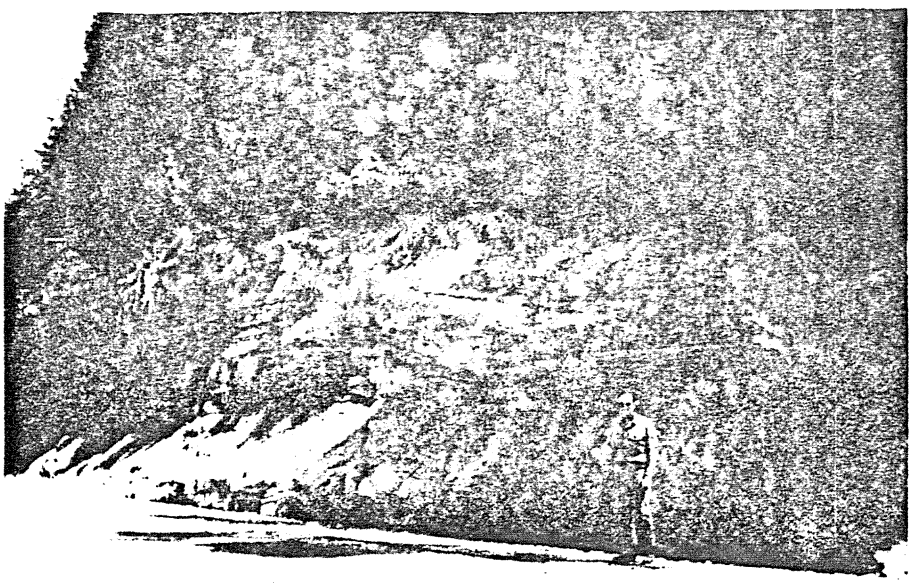

FIGURE 3. Mazama Pumice, water worked deposit North of Union Creek, Rogue River N. F.

FIGURE 4. Mazama Pumice (nuee ardente) Wocus Bay, Winema N. F.

SUMMARY OF EXPERIENCE OUTSIDE OF OREGON

Pumice soil exists in many parts of the world, the principal ones being Central America, New Zealand and west and southwest United States. Finer grained volcanic material from ash form tuff or plastic clays as found in Japan, Hawaii and Italy. These latter types of material were not investigated as Oregon pumice is coarse grained and non-plastic.

California

California pumice and the resulting road construction problems are similar to that of central Oregon. The principal areas of pumice in California are located in the northern part of the State. The California Division of Highways has used pumice only to a limited extent as a structura section material. Some attempts have been made to stabilize the material with bituminous material, but results were poor due to a tendency of the surface to spall or ravel and because of the high absorptive and porous characteristics of the pumice. A cement treated base was not considered successful due to problems in trimming the final section. The only successf use of pumice is for embankment construction and subbase material (5). Region 5 (California) of the Forest Service is currently undertaking a test program to evaluate pumice as a surface course material.

New Mexico

Pumice in New Mexico usually occurs mixed with ash to form pumiceous tuff. The State Highway Department has had very little experience with pumice; however, an investigation by a private firm in the Los Alamos area

did determine the effect of cement treatments. Their conclusions were that pumiceous tuffs could be stabilized with cement contents as low as 2 to 3 percent for subgrades. In addition, compaction requirements could be lowered, especially when the material was used as backfill in utility trenches. Their conclusions were based on unconfined compression tests (6).

New Zealand

The largest pumice soil region of New Zealand is described as humid-temperate with 45-60 inches of precipitation annually. Central Oregon receives only 15 to 25 inches in comparison. The New Zealand material is rhyolitic in composition, and their soil is weakly weathered, similar to Oregon pumice (7), (8). Because of low crushing strength and low density, untreated pumice is not usually regarded as a satisfactory wearing surface, as it produces extreme dusting in dry conditions, and rapid scouring under even moderate rainfall. Since pumice is non-plastic, it is used effectively as subbase material with CBRs of 20 to 40, and with a thin wearing course can be used as a base material. When stabilized with cement, it is necessary to apply a chip seal. Shrinkage cracks occur, but are minimized by reducing the cement content (to 250-450 psi unconfined compressive strength at 7 days) and sealing with a chip seal. Some problems have developed in achieving adhesion of the chip seal to the stabilized material. Using a cationic emulsion and power brooming before the application has improved this condition. The size gradation of pumice is critical when used in cement stabilization, to prevent the use of the cement simply as a filler.

Moderate results have been obtained using asphaltic cut backs for stabilizations. Limited test work has been carried out using lime, with some pozzolanic action obtained, however the high cost of lime limits its field application. The fine pumice ash soils are almost impossible material for engineering use, having very high field moisture contents. Pumice cut and fills are prone to surface erosion by rain and, in general, near vertical slopes give the best performance (9),(10), (11).

Guatemala

Fine grain pumice soils in Guatemala(96% passing No. 4 sieve and more than 20% passing No. 200 sieve) have been analyzed and observed as to their behavior as a highway construction material. Guatemalan soils never experience freezing and thawing, only dry and rainy seasons, thus weathering effects are somewhat different than that of Oregon. Compaction procedures were one of the tests investigated. Results indicated that excessive compaction caused degradation with subsequent change in the compactive characteristics and the compaction curve. In most cases compaction of 100% of Modified Proctor density (AASHO T 180) was impossible to obtain. Their feelings were that with materials of this type compaction to a specified degree was unnecessary due to the cohesionless nature of the soil. Adequate compaction is obtained when heavier equipment no longer shows ruts or displacement under its wheels. Degradation obtained in the field is closely related to that obtained under the Modified Proctor test or static compression test. Compaction was best achieved by means of a

vibratory compactor with the addition of water to the pumice (12).

Good results were obtained in the laboratory by stabilizing pumice with 2 to 3 percent cement and 1 to 5 percent hydrated lime. Asphalt stabilization using RC-2 produced mixed results. Some pumice samples exhibited good stability coating and adherence in the presence of water; others did not. The average asphalt content for good stability was 6 to 8 percent.

FIELD INVESTIGATION - REGION 6

As part of the pumice study, visits were made to organizations in the central Oregon pumice zone to interview individuals familiar with pumice construction and to observe current low-class road construction procedures on pumice. The organizations contacted were:

Winema National Forest, Klamath Falls
(Supervisor's Office, Chiloquin and Chemult R.D.)

Deschutes National Forest, Bend
(Supervisor's Office)

Rogue River National Forest, Medford
(Supervisor's Office, Prospect R.D.)

Oregon State Highway Department
(Salem and Bend)

Gilchrist Lumber Company, Gilchrist

Crown-Zellerbach, Beaver Marsh

Klamath County Road Department, Klamath Falls

The more significant observations are discussed below.

Winema National Forest

Road construction on the Winema National Forest in pumice soils (generally subaerial) is typical of most of the adjacent Forests. Cut and fill sections are made of existing material with little consideration for gradation or soil horizon. In cut sections the cut is made to subgrade elevation and the structural section constructed as a fill of material from ditch excavation or other excavated pumice (see Figure 5). In fills pumice will stand as steep as 1:1 (approximate natural angle of repose); however, flatter slopes are normally used to prevent excessive erosion. For smaller projects, compaction is limited to that obtained from construction equipment operating over the fills. Roads constructed by contract require compaction (F.S. Item 51, Excavation); however, some difficulty has been encountered in setting and achieving compaction standards. Distinctive compaction curves have been obtained in the laboratory by Forest Service personnel; however, the author was only able to obtain a random scattering of points on similar material. Field compaction has been achieved by requiring a given number of passes of the compaction equipment and not by requiring a percent of maximum density as determined by AASHO Test Method T-99. During the summer logging period some stabilization is attempted by watering; however, this is generally futile due to rapid percolation and evaporation. Severe dusting is typical and often a safety hazard due to limited visibility. Some stabilization has been attempted with dust oil,but the results were not conclusive. On the heavier traveled roads, six inches of volcanic cinders are used to cover the pumice subgrade to solve the dusting and rutting problem.

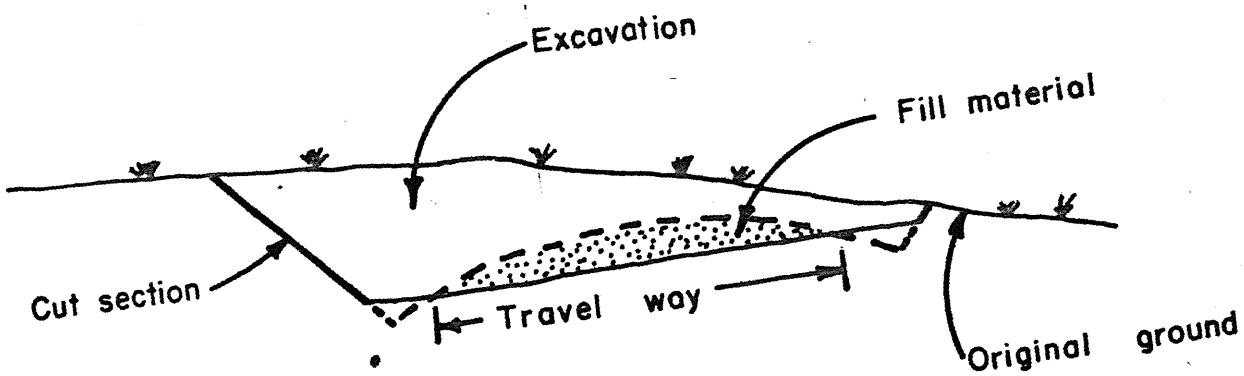

FIGURE 5. Typical Cut Section – Forest Service

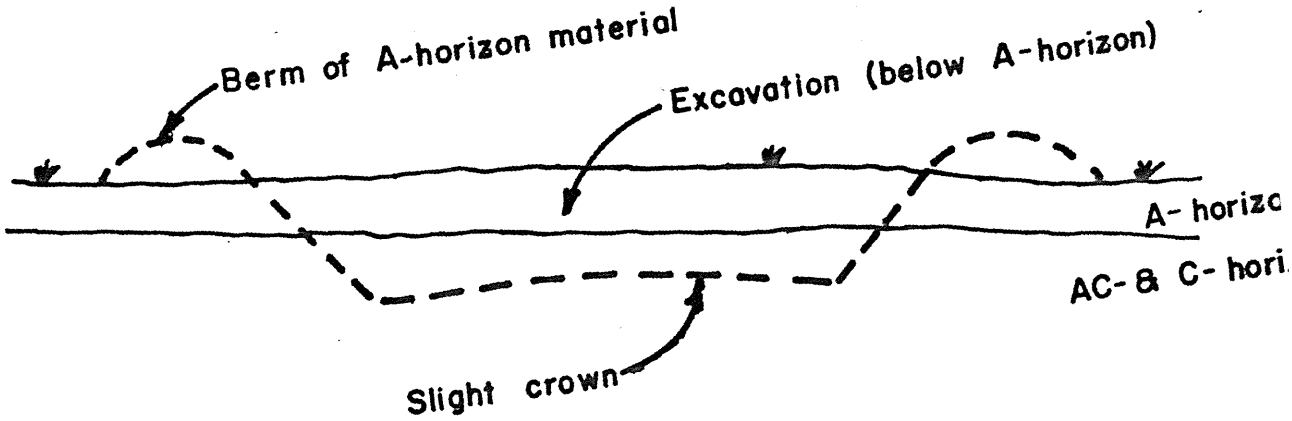

FIGURE 8. Typical Cut Section – Gilchrist Lumber Company

Rogue River National Forest

The construction procedures on the Rogue River National Forest (mainly on the Prospect R. D.) are somewhat different than those of the Winema or Deschutes National Forests. Pumice in this area consists primarily of nuee ardente (glowing avalanche) from Mt. Mazama or water redeposits of this material. In some cases the nuee ardente deposits are several hundred feet thick along the Rogue River. During deposition the nuee ardente material was fused together by the high temperatures associated with the formation (local Forest Service personnel feel this may also be due to mechanical interlock). The end result is that there is a wide range of particle size (boulders to dust) and because of the cementing action, cuts can be made to stand near vertical (Figure 6). However, once this cementing action is disturbed it cannot be regained -- thus fill slopes are somewhat unstable and subject to erosion. Dusting does not appear to be as severe as that from subaerial deposits. In place densities have a CBR value from 13 to 20. Some deposits in the area are so stream washed that only the heavier particles remain. This material behaves similar to a poorly graded sand(Figure 7).

Oregon State Highway Department

The Oregon State Highway Department has had very little experience using pumice as a wearing surface or stabilizing the material for base or subbase material. Several suggestions for stabilizing pumice were suggested; one being fuzing pumice with borox (eutectic point of 8-900^{o} F) producing a laminated surface to build up strength; the other was to make a gunite type

FIGURE 6. Nuee ardente Deposits, Copeland Creek Rd., Rogue River N. F.

FIGURE 7. Sand-pumice, River Road, Rogue River N. F.

of cement with pumice and apply this to the roadbed as the structural section.

A recent maintenance contract north of Chemult used a heavy vibratory roller to compact roadway shoulders of pumice prior to paving. Excellent results were obtained. Standard Proctor (AASHO T-99) results for this material gave a maximum dry density of 57.4 pcf and an optimum moisture content of 59.3 percent.

Gilchrist Lumber Company

Gilchrist Lumber Company has used pumice as a surfacing material for their private logging roads during the past 35 years. They prefer the pumice surface as this produces a minimum of wear on logging truck tires -- 200,000 miles on a set of tires is not uncommon. The main source of surfacing material is volcanic cinders. In their area of operation, however, they elect not to use cinders due to the excessive tire wear it produces.

Their construction procedure differs from that of the Forest Service. During construction they remove the gray A horizon material, as this is fine-grained, weathered, organic material producing a poor surface. The A horizon material is pushed up into a berm on either side of the roadway and the travel lane is built upon the yellow or pink AC and C horizon material. The road is thus constructed in a trench section, rolling with the topography (See Figures 8 and 9). Only a slight crown section is used as excessive crown tends to cause trucks to slide off the road in the winter. Large cuts into the underlying buried silty soil are avoided.

No culverts are used, drainage being obtained by relief ditches pushed out at frequent intervals by tractors(Figure 10). Ditch sections are used in some areas. Maintenance during summer logging operations is accomplished by watering at night at the rate of 3000 gal. per mile per day. They feel this provides for better water retention during the day; however, they admit that this surface moisture has usually evaporated by noon. Blading with graders is performed every 2 or 3 days with only the top half inch of material reworked. During the winter the pumice soil will freeze to a depth of 18 inches (due to low heat capacity and conduction, pumice lacks the ability to store as much heat as more dense soils (13)). As a result, hauling on pumice roads is excellent in the winter, with the only maintenance being snow removal. During spring thaw the soil will rut until it has thawed to a depth of 6 inches. In some areas soils consisting of silty outwash from pumice is encountered (probably Collier soil series). This material is very poor and is avoided if possible. Gilchrist Lumber Company is, in general, very satisfied with their pumice roads, as they are efficient and require only a minimum of maintenance.

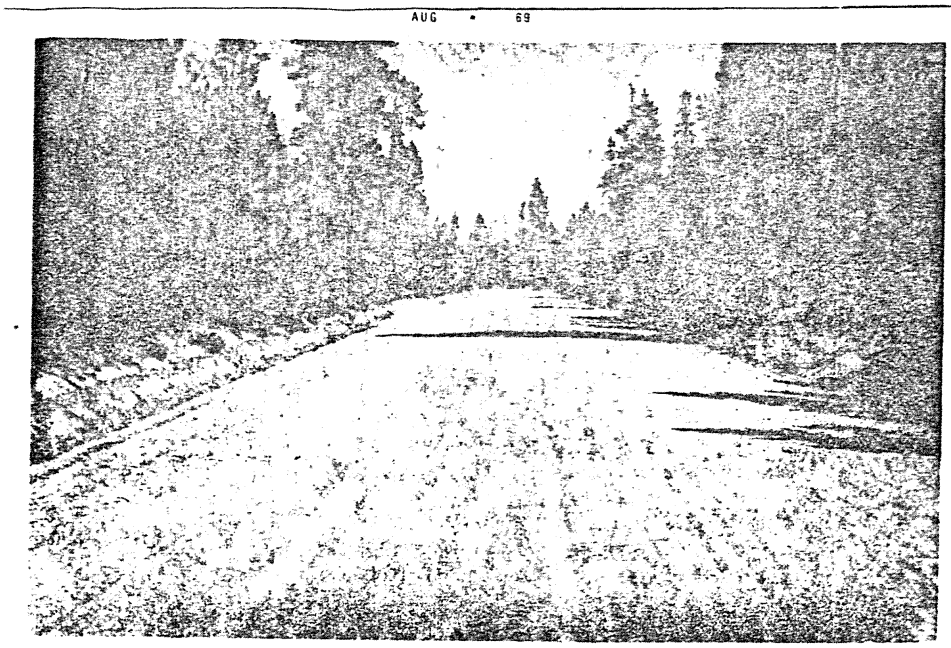

FIGURE 9. Gilchrist Logging Road, near Gilchrist, Oregon

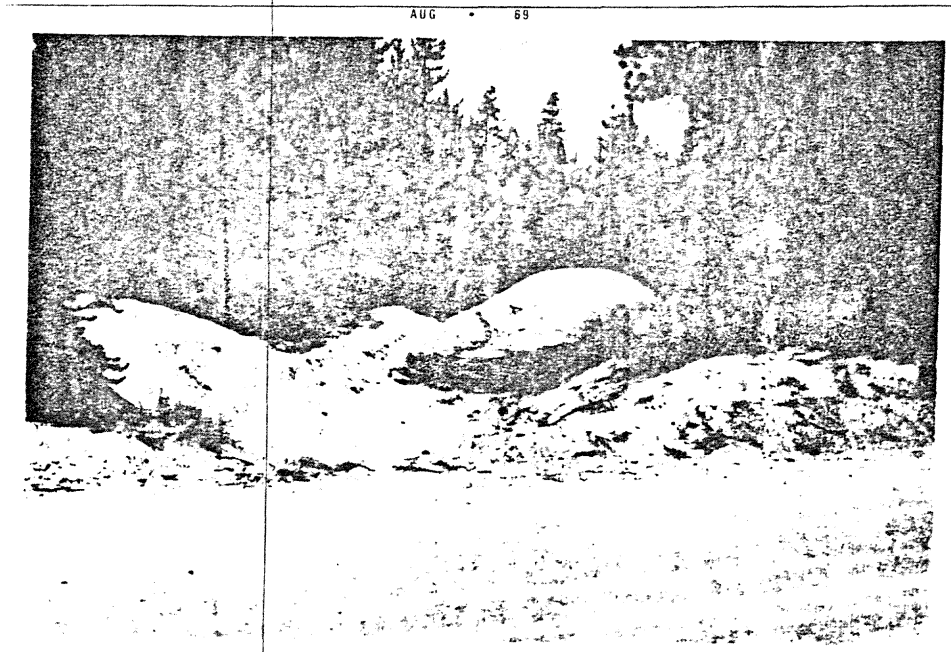

FIGURE 10. Relief Ditch on Gilchrist Logging Road

WINEMA NATIONAL FOREST INVESTIGATION

It was evident from the literature review and the field observations that very little information was available on construction techniques and stabilization methods for pumice. This problem was compounded by the many different forms of pumice deposits and the resulting gradations. Consequently, a testing program was undertaken to determine the most efficient use of pumice for a road building material in Region 6. Since Mt. Mazama pumice was the most prominent type in this area it was decided to sample material from this source. The investigation would consist of two parts, laboratory testing and a field test road. The details of these two investigations are presented in the following sections.

Laboratory Testing

Laboratory testing was undertaken to determine what type of stabilization appeared to be most beneficial for pumice and to determine the optimum percentage of additive. Initially, samples of pumice from various Forests in Region 6 were to be tested but, due to time limitation and the wide variety of pumice deposits, only samples from the Bear Flat Road, a proposed test road, were tested.

Representative samples from Sta. 30+00 on the test road were obtained from the C horizon material. The A horizon material was not sampled as it contained organic material and would not be used on the test road. During sampling it became apparent that even the C horizon material varied in gradation with depth as illustrated in Appendix A.

Based on the literature review and consultations with various Forest Service Materials Engineers, the following additives were tested:

Hydrated Lime

Type II Cement

Clay from a local Cinder Pit (Skellock)

Bituminous Stabilizer 120

SS-k emulsion

The main problem that developed was the manner in which to evaluate the performance of these additives. The stabilized pumice was to be used as a wearing surface on Forest access roads; thus the desirable properties would be abrasion and degradation resistance, low dusting, smooth riding quality, stability, and a minimum of maintenance, with low dusting being the most important on pumice roads. Several methods have been used to evaluate stabilizing agents, the most common being a circular test track and unconfined compression tests (14) (15). A test track has been used in Washington State University research and testing at the Forest Service Materials Laboratory for Region 5. The results are measured principally from a qualitative nature with some quantitative measurements being taken. However, it is difficult to evaluate dusting except from a qualitative point of view. The unconfined compression testing gives very little, if any, information concerning abrasion and dusting properties, but does give an indication of the stability of the mixture and the optimum additive percentage to use. Outside of an actual field test, there appeared to be no satisfactory method of evaluating the dusting and abrasion problem. An

indication of the proper percentage of additive for stability, and an indication of the possible mixing and curing problems had to be known to prevent costly trial and error procedures in field test sections.

Since unconfined compression testing is relatively easy to perform and ample comparison data are available, this method of evaluation was chosen.

The procedures followed used 2-inch diameter by 4-inch long specimens compacted under static compression of approximately 700 psi. The specimens were then tested after 7 days at the rate of 0.05 inches/minute to failure (Figure 11). The details of the preparation and the test procedure are listed in Appendix B.

The hydrated lime and cement samples were mixed at 2, 5 and 10 percent by weight (using a pumice dry density of 60 pcf). No problems were encountered in their preparation and testing. The clay sample from the Skellock Cinder Pit was mixed at 10, 20 and 30 percent by weight. Both dry cured and moisture cured samples were tested. Some difficulty was encountered in mixing the asphaltic specimens. The BS-120 samples were mixed as 10, 15 and 20 percent by weight. The SS-k emulsion was mixed at 15, 20 and 30 percent. These higher percentages of the latter type were necessary due to difficulty of mixing and coating the pumice particles at smaller percentages. The 15 percent emulsion sample disintegrated during the soaking sequence. The BS-120 samples had 5 percent moisture at the time of mixing as recommended in Forest Service construction specifications (16), and the SS-k sample had 20 percent moisture.

The BS-120 asphaltic material appeared to be the only type that would coat the pumice particles at low asphalt contents. The CM-k and SS-k mixtures resulted in poor coating and mixing (Figure 12). Time prevented testing an MC or RC, but it is doubted that they would reduce the coating problem.

The hydrated lime gave the best strength, with cement being the next best at low percentages of additive. The asphalt specimens gave a typical stability curve, the optimum being approximately 10 percent for BS-120 and 30 percent for the SS-k. The moist clay specimens (humid cure) showed no increase in strength; however, the dry clay specimens (room cure) did increase in strength with increasing percentage of clay. There was some increase in density with increasing clay content. The cinder clay used was from weathered red cinders with a PI of 7 and an LL of 35. The results of the testing are summarized in Figure 13; these values and unsoaked results are reported in Appendix C.

Test Road

The test road was located in the Chemult District of the Winema National Forest. Approximately one mile of the Bear Flat Road (#286) was to be relocated from the Junction of the Silver Lake Road (approximately 20 miles east of U. S. 97), and then tie back into the original road (Figure 14). Station 5+00 to station 38+00 was designated for special construction (i.e., for stabilization and all cuts to be below the A horizon) (Figure 15); station 38+00 to station 60+00 was to be constructed by normal Forest Service standards.

The largest cuts on the project were approximately 5 feet in depth (Sta. 11 to 17; sta. 25 to 30; and sta. 46 to 55). The latter two cuts

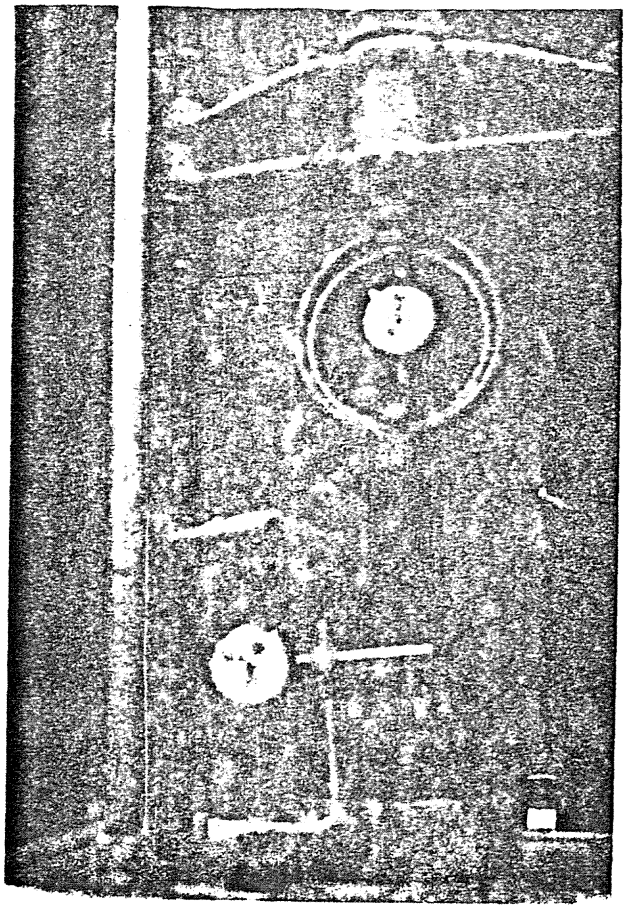

FIGURE 11. Unconfined Compression Testing of Stabilized Pumice Samples

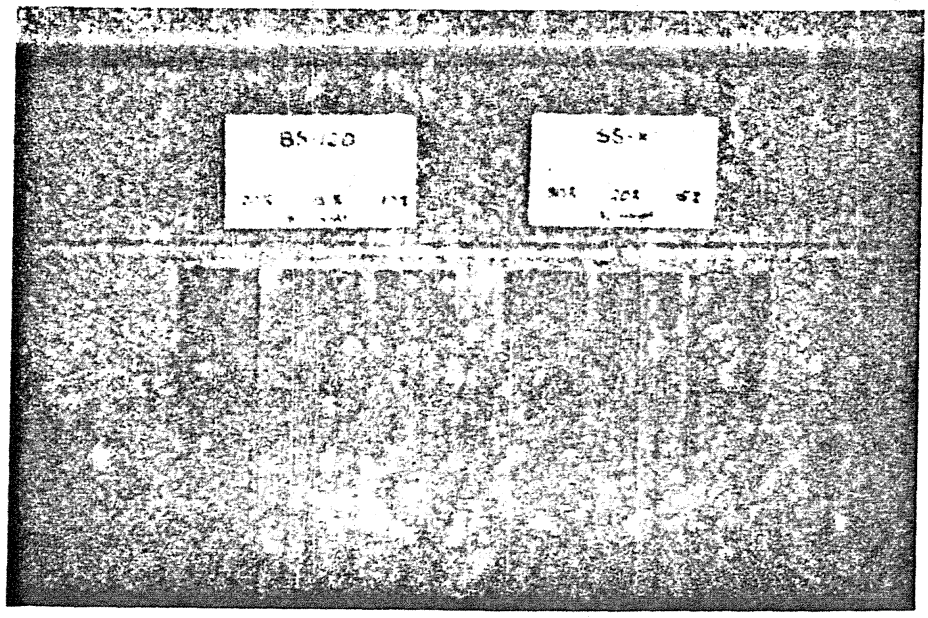

FIGURE 12. Comparison of BS-120 and SS-k Treated Pumice Samples from Bear Flat Road.

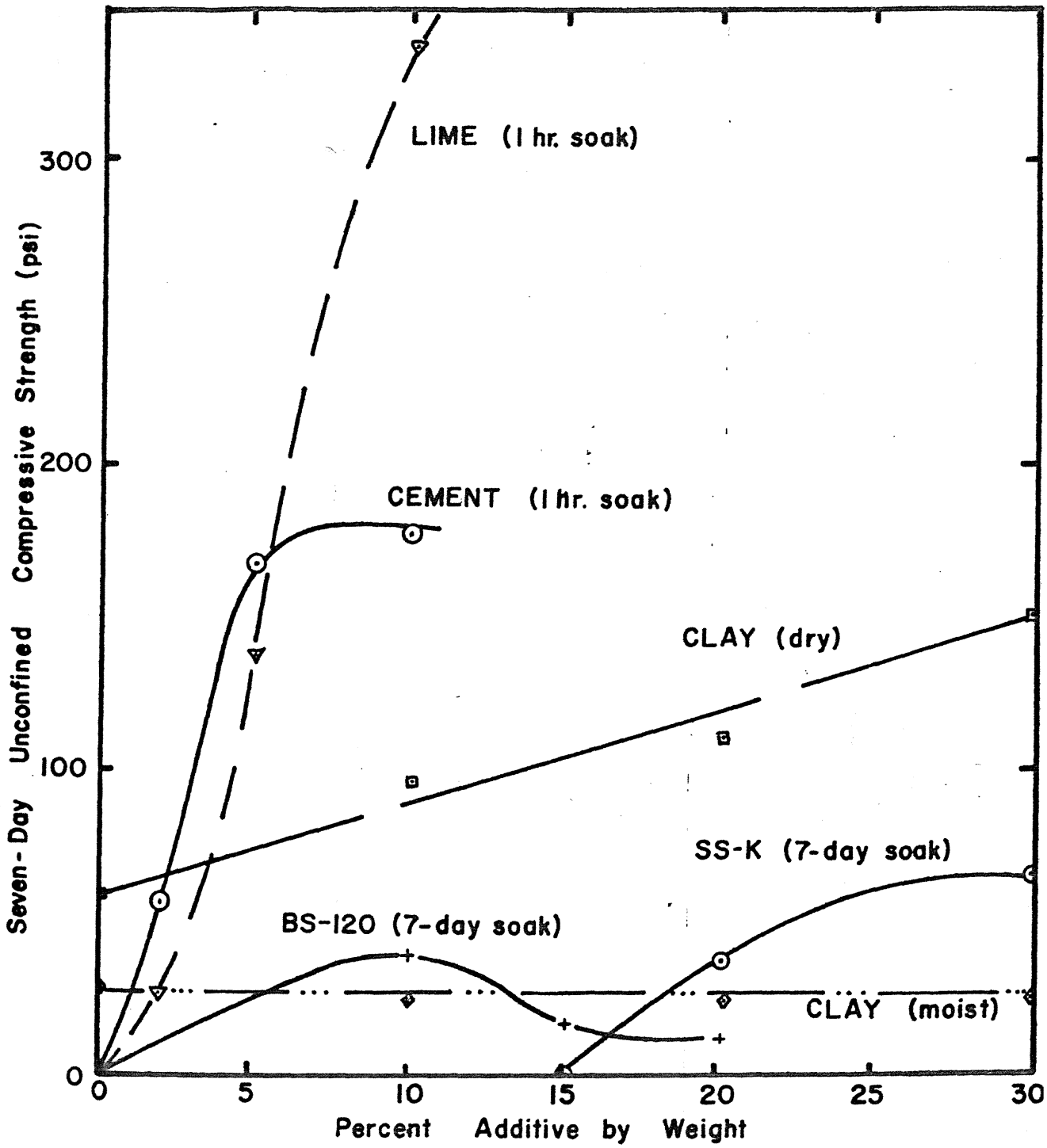

FIGURE 13. Pumice Stabilization Test Results

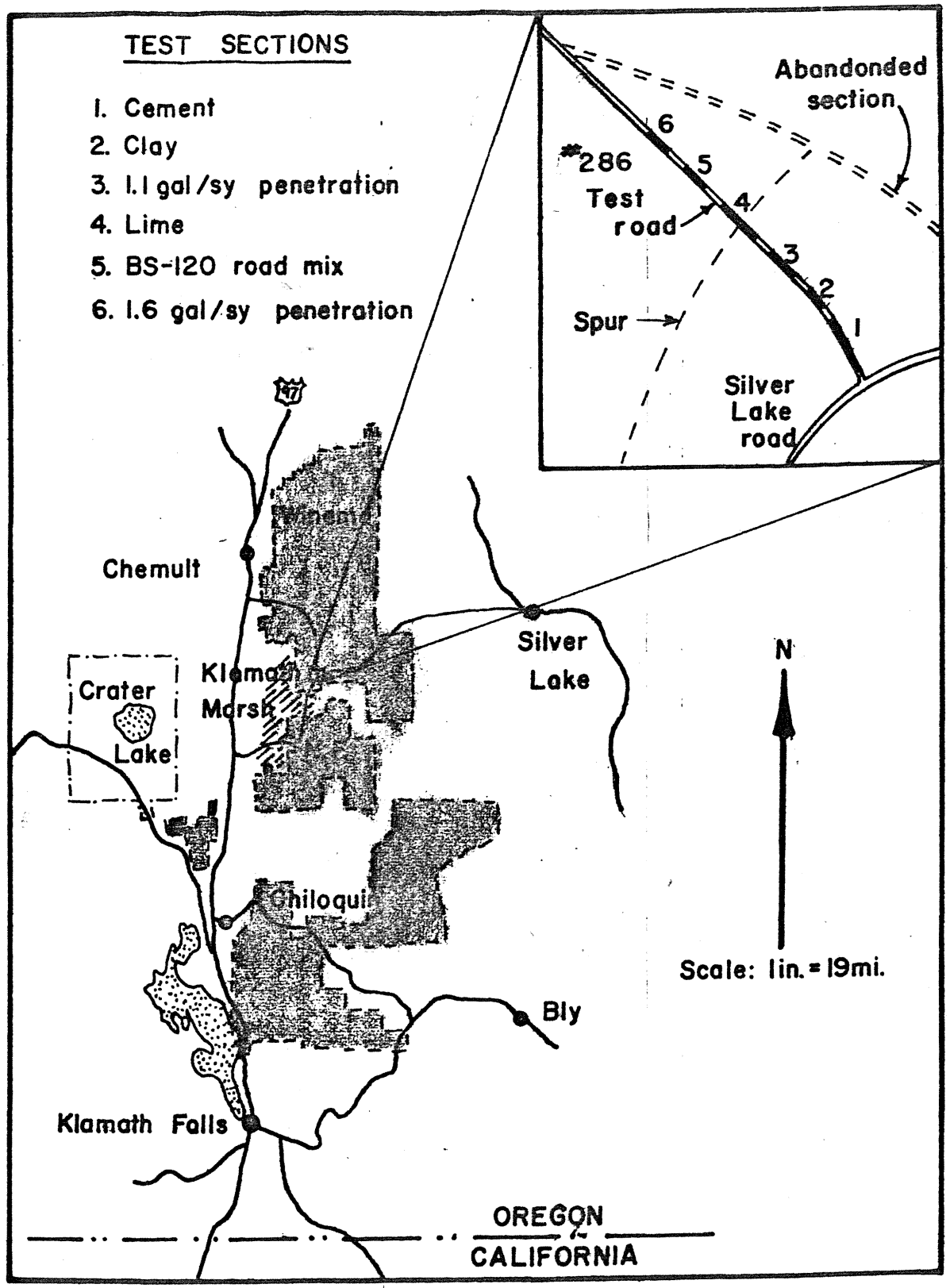

FIGURE 14. Test Road Location

were generally less than 5 feet. The maximum fills were approximately 3 feet in depth. Several sand pockets were encountered (probably pumice and basalt alluvium of Collier Series) causing construction equipment to become stuck (sta. 15 to 16 and sta. 25+50 to 28). These pockets were excavated to a depth of about 3 feet below grade, deposited in the bottom of an adjacent fill and the resulting hole backfilled with pumice.

The pumice encountered on the job was both of the subaerial type and the nuee ardente type, giving a wide range of gradation both along the cent line of the project and with depth. Fine sand to boulder size particles were encountered. This presented some problems in analyzing the effect of the stabilization process.

The test road was constructed with six major stabilized sections. Eac of these sections was separated by an untreated section of at least 200 feet. The stabilized sections were placed in cuts made below the A horizon material and on tangent sections. The following stabilized sections were constructed:

400 feet of 5% cement (the last 200 feet was covered with 0.4 gal/sy of BS-120 penetration)

200 feet of 30% cinder clay

400 feet of 5% hydrated lime (the last 200 feet was covered with 0.3 gal/sy of BS-120 penetration)

300 feet of 1.1 gal/sy BS-120 penetration

300 feet of 1.6 gal/sy BS-120 penetration

200 feet of 15% BS-120 road mix

These test sections were constructed on the first part of the project (sta 5 to sta. 38) with untreated sections in this part of the project being compacted with the compaction equipment. The typical cross section was similar to that used by Gilchrist Lumber Company and illustrated in Figure 8. The remainder of the project (from sta. 38 to sta. 60) was constructed according to Forest Service standards, as illustrated in Figure 5. The typical cross section was 24 to 26 feet wide with a 5% crown section. The stabilized sections were constructed from September 3 to 8, and the entire road was opened to traffic on September 12.

Compaction .

The late start in constructing the project (late August to early September) made it difficult to obtain compaction equipment due to the fall construction rush in the area. A rubber-tired roller with electric steering was finally obtained. Empty, it weighed approximately 12 tons, and loaded with water approximately 20 tons. It could also apply water to the grade by a sprinkler bar when the water truck was not available. Unfortunately, the roller broke down on the final day; thus, the water truck and the rubber-tired scraper had to be used to compact the final lift of the BS-120 road mix. A vibratory roller would probably have worked better than a rubber-tired roller, as indicated by the use of one on a local State Highway construction project compacting pumice shoulders; however, one was not available at the time of construction.

Cement Treated Section

Station 7 to 11 was road mixed with Type II cement. A section 400 feet long, 24 feet wide and 6 inches deep was scarified by a grader and 14,400 lbs of cement (154 sacks) was mixed into the pumice. This gave a cement content of 5% by weight using a pumice compacted dry density of 60 pct. The cement sacks were placed and emptied by hand. After thorough mixing with a grader, approximately 4000 gals. of water were added to bring the pumice from its natural moisture content of 10% to the optimum of 40% (Figure 10). The final mixture was then compacted by the rubber-tired roller. Approximately 1½ hours were required to place and mix the cement dry and an additional 1½ hours were used to mix and compact the mixture after the water was added. The section was watered lightly for approximately 3 days. Unfortunately, the ground froze over night on the days following construction, causing the surface to "fluff" with many loose particles.

After 5 days, shrinkage cracks had developed approximately 12 inches across. At this time 200 feet (sta. 9 to 11) was treated with 0.4 gal/sy of BS-120 penetration (at 150° F)(Figure 17). The next day this had penetrated 1/8 to 1/4 inch and could be driven on by traffic. Within a month the penetration treatment had broken up, especially in the center of the roadway. This was probably due to the "fluffing" caused by the frost (Figure 18). This may have been prevented by brooming before the applicati of the BS-120. The 200 foot section without the penetration treatment als had a loose surface; however, no structural failures have been observed in the 6 months since construction. The site was visited in February. At th time the ground was still frozen with the top inch loose and saturated due to daytime thaw. The penetration was almost entirely broken into small pi

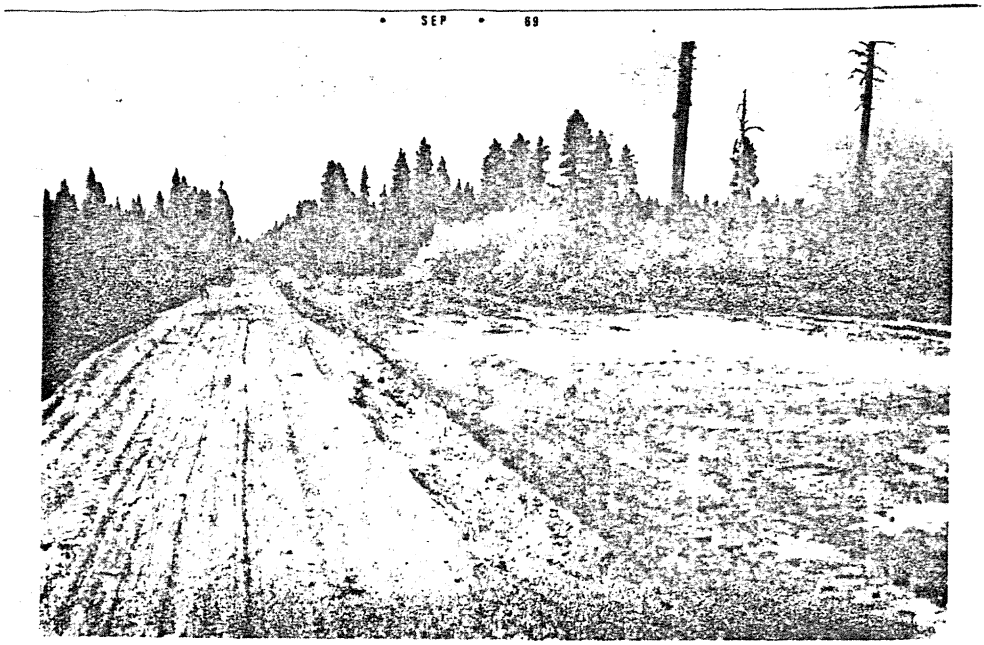

FIGURE 15. Bear Flat Road Construction. Note dusting due to Self Loading Scraper

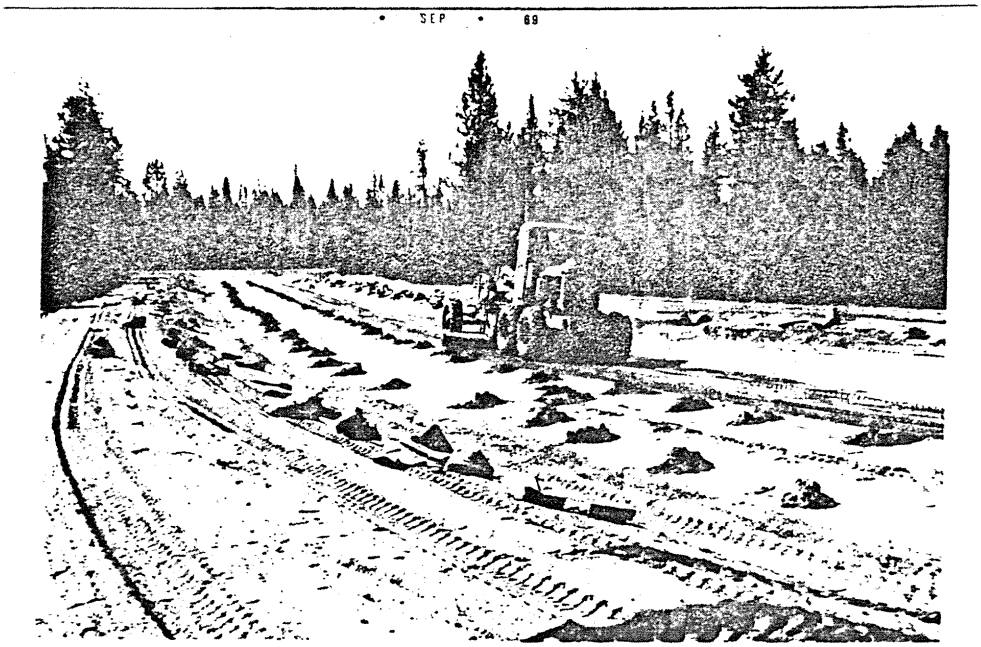

FIGURE 16. Cement Treated Section - Spreading Cement

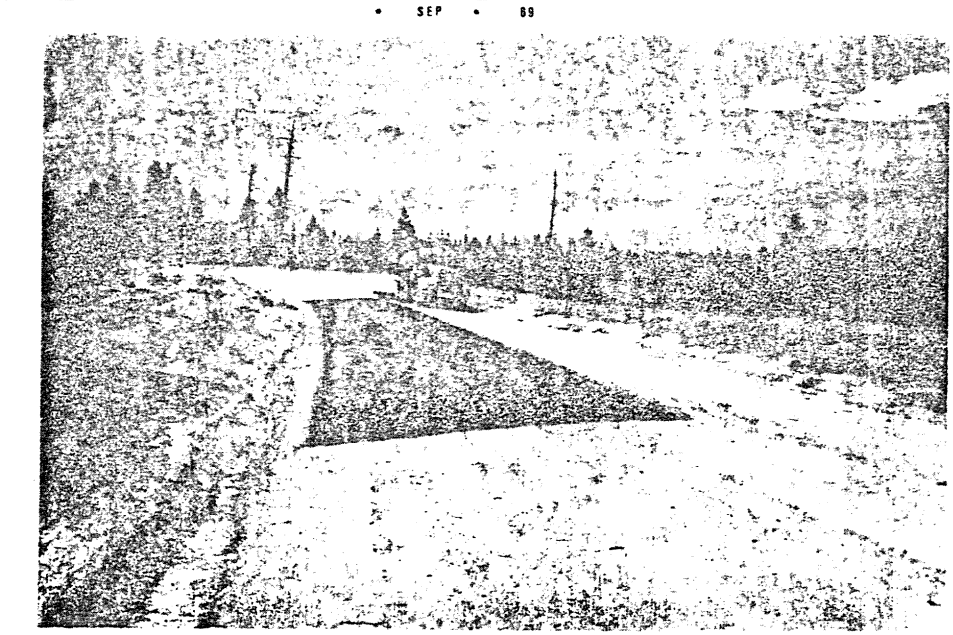

FIGURE 17. BS-120 Penetration Treatment of Cement Stabilized Section at 0.4 gal/sy

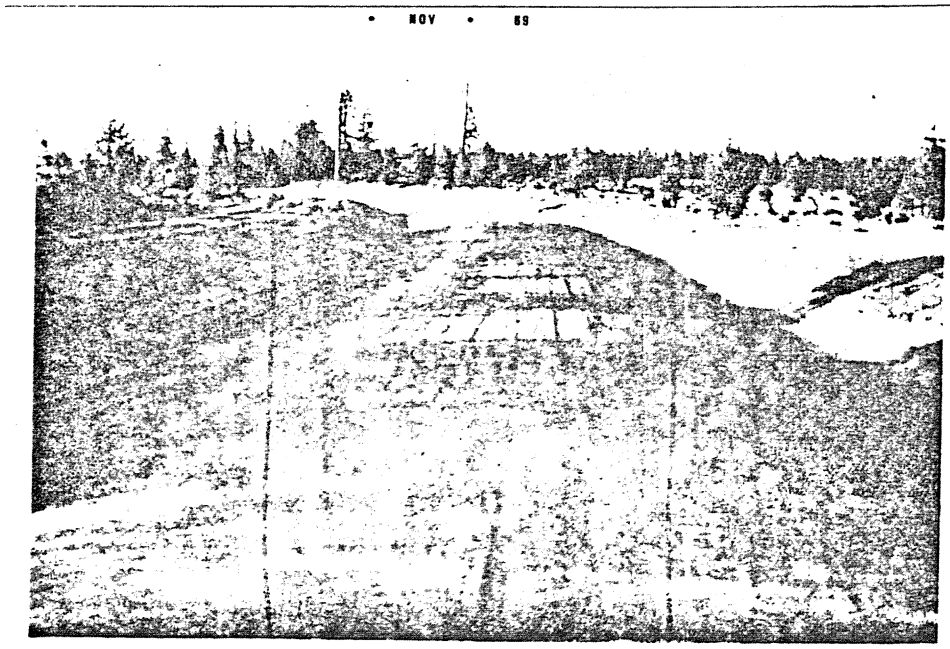

FIGURE 18. Same as Figure 17 approximately 2 weeks later. Note failure of Penetration Treatment in Center

Lime Treated Section

Station 22 to 26 was road mixed with hydrated lime(Miracle Boulder Canyon Lime) at 5% by weight. A section 400 feet long, 24 feet wide and 6 inches deep was scarified by a grader and 14,400 lbs. of lime was mixed with the pumice. Construction procedures were similar to those used in the cement section. The entire section was mixed, watered and compacted with 4000 gallons of water in 3 hours (Figure 19). At this moisture content the section appeared almost too wet; however, no mixing problems were encountered. This section also froze overnight; however, due to the slow setting of the lime, rolling was able to compact the loose surface the next day. In four days a 6-inch diameter crack pattern had developed. At this time 200 feet of the section (sta 24 to 26) was treated with 0.3 gal/sy of BS-120 penetration (at 150° F). The next day this had penetrated 1/8 to 1/4 inch. In two months of use the penetrated section was slightly raveled, but not as bad as that on the cement section. The portion without penetration treatment was still smooth and dust free at this time.

Clay Section

Thirty-six cubic yards of cinder clay from Skellock cinder pit (approximately 11 miles south of the project) was stockpiled on the job to give a mixture of 30% by weight. A section 200 feet by 24 feet by 6 inches deep (sta. 13 to 15) was scarified and the clay mixed with the pumice. Over-size material (+ 3 inch material) consisting of cinders and basaltic pieces were hand picked from the mixture. After mixing, the material was watered and compacted. It took four hours to complete the operation as some difficulty was encountered in mixing the material due to the large volume (Figure 20).

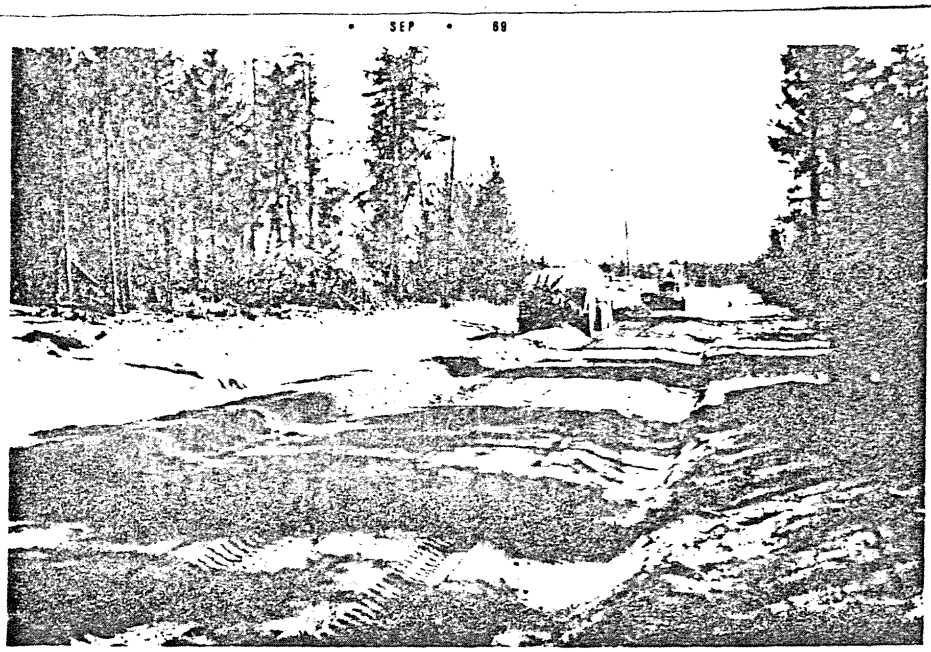

FIGURE 19. Watering and Mixing Lime Treated Section

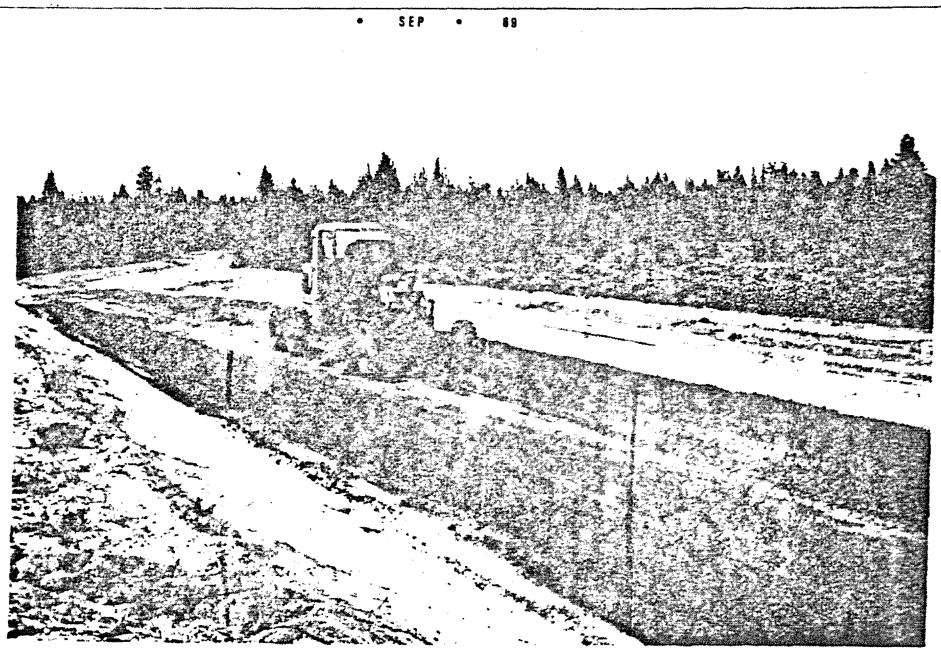

FIGURE 20. Mixing Cinder Clay Treated Section

The treated section set up well and gave a smooth riding surface. Again in November the surface was still smooth and dustless. By February the surface was saturated due to the thaw of the frozen ground; however, the surface was still smooth, showing very few ruts as contrasted to the adjacent untreated pumice sections.

Road Mix Section

Station 29 to 30 was road mixed with BS-120 asphaltic material at 15% by weight. A section 200 feet long, 24 feet wide and 6 inches deep was scarified and windrowed in preparation for the asphaltic material. The pumice was used at its natural moisture content (10%) as a small percentage of moisture was recommended by specifications (16). Four applications of BS-120 were necessary to add the desired percentage of asphalt with mixing performed between each application. (Figure 21). Half of the processed material was placed and rolled. Compaction was achieved using the water truck, as the roller was out of service at this time. The remaining half was windrowed to allow the first lift to cure. The latter half was placed and rolled the following day. The final mix appeared well processed with no fat or lean spots. The final thickness was considerably less than the desired 6 inches resulting from an unusually high degree of densification of the mixture. By November the surface had some cracking and wheel path rutting. The rutting was caused by the slow evaporation of volatiles, as fall weather did not allow for adequate curing. The surface at this time was smooth with some raveling near the shoulders (Figure 22). During the February visit to the project, the surface was still very smooth with a

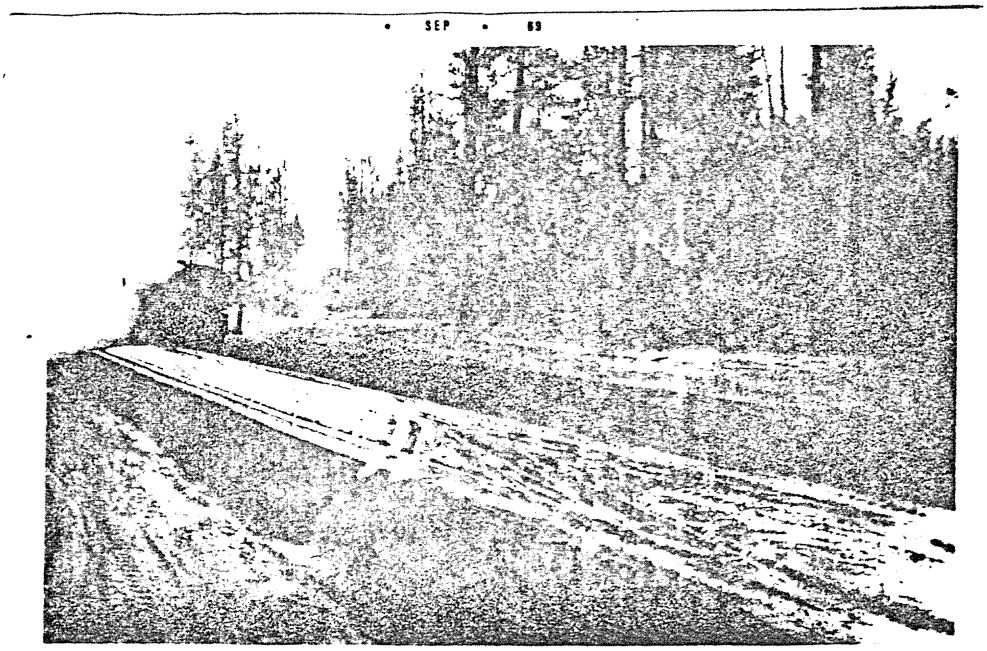

FIGURE 21. Second Application of BS-120 to Road Mix Section

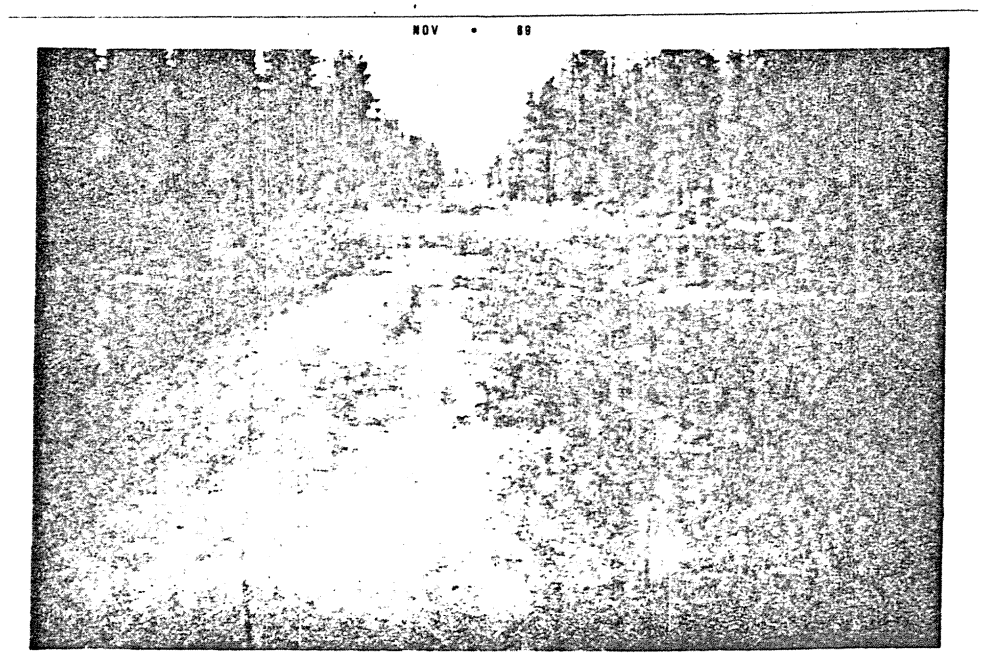

FIGURE 22. Road Mix Section approximately Two Weeks after Construction

few potholes; however, the entire surface was soft and pliable. Upon further investigation it was determined that the entire thickness, except for the top inch, was very plastic due to lack of curing.

Penetration Treatments. (Sta. 33-36)

A section 300 feet long by 24 feet wide was bladed and rolled prior to application of the asphaltic material. The first application of BS-120 was approximately 0.9 gals/sy (maximum output of the distributor) at 150° F. Two hours later an additional application of 0.7 gals/sy was applied for a total of 1.6 gals/sy. The material had good penetration except where several wet spots existed from water truck leakage (Figure 23). By the next day the material had penetrated approximately 1 inch with some wet spots on the surface. These spots were sanded the following day. Traffic caused the section to ravel almost immediately and by November the penetrat areas were broken into small pieces and the pumice had washboarded and rutt

(Sta. 17-20) This section was prepared and treated much the same as the above section. The total application (applied in two layers) was approximately 1.1 gal/sy (Figure 24). By the next day the BS-120 had penetrated 1/2 inch into the pumice, but could not be driven on at this time. A small section near Sta. 17 had to be removed due to the soft sand area mentioned earlier (Page 25). By November the section had many areas which were raveled and broken into small pieces, although not as bad as the 1.6 gal/sy section (Figure 25).

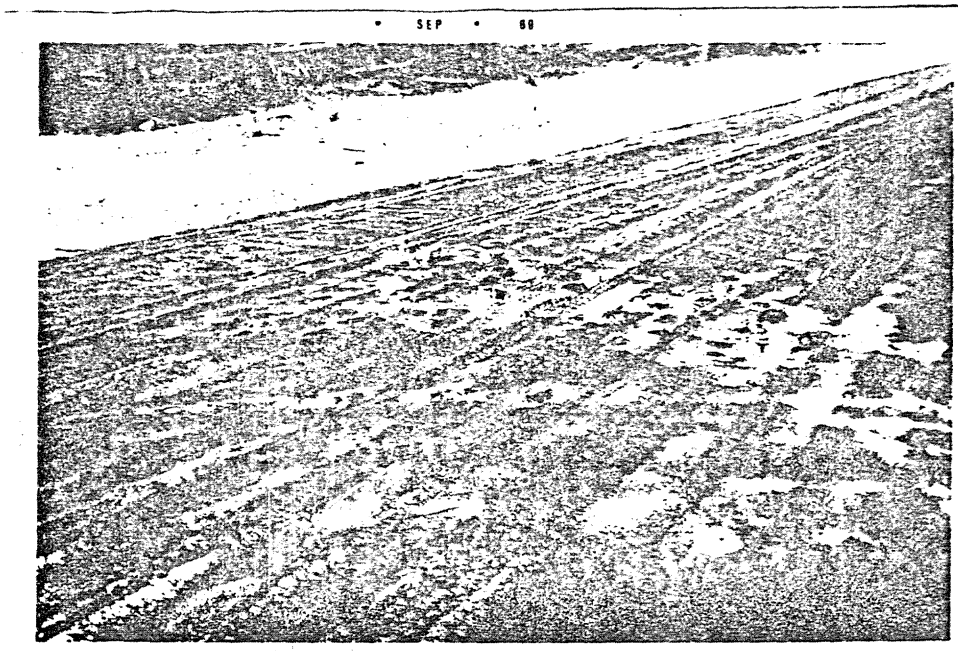

FIGURE 23. First Application of BS-120 on 1.6 gal/sy Penetration Section. Note lack of Penetration where leaking Water Truck crossed.

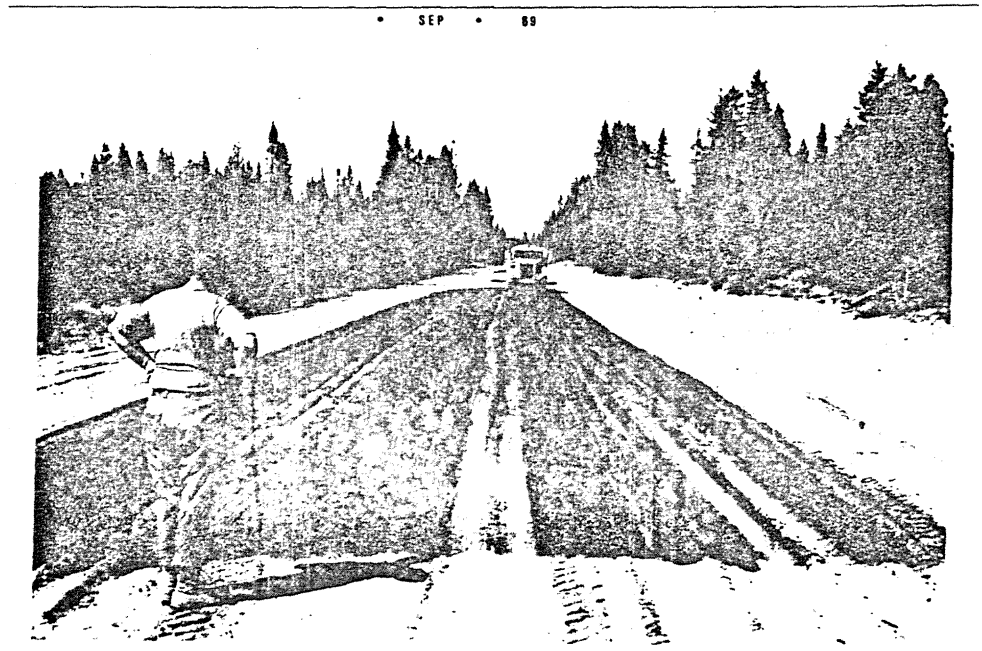

FIGURE 24. First Application of BS-120 on 1.1 gal/sy Penetration Section

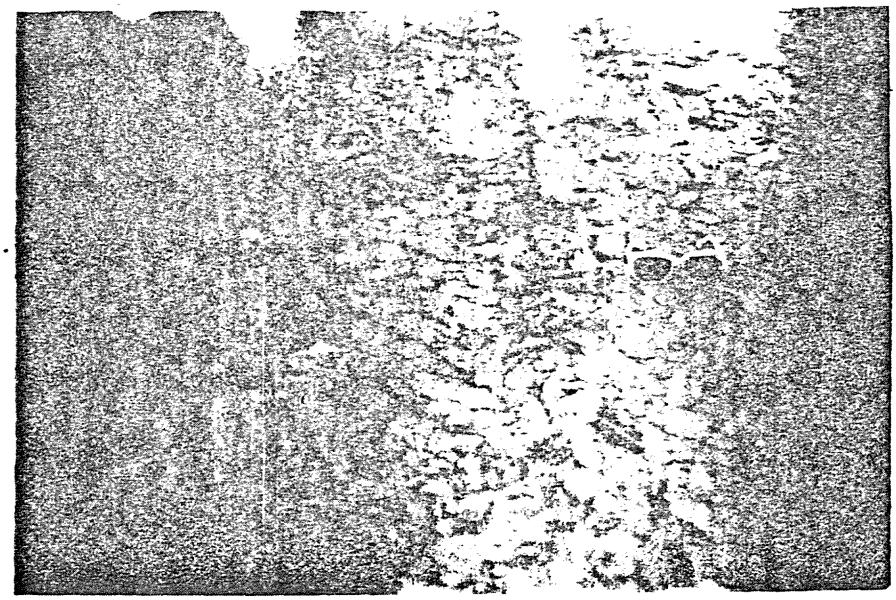

FIGURE 25. 1.1 gal/sy BS-120 Penetration Section approximately 6 months after Construction

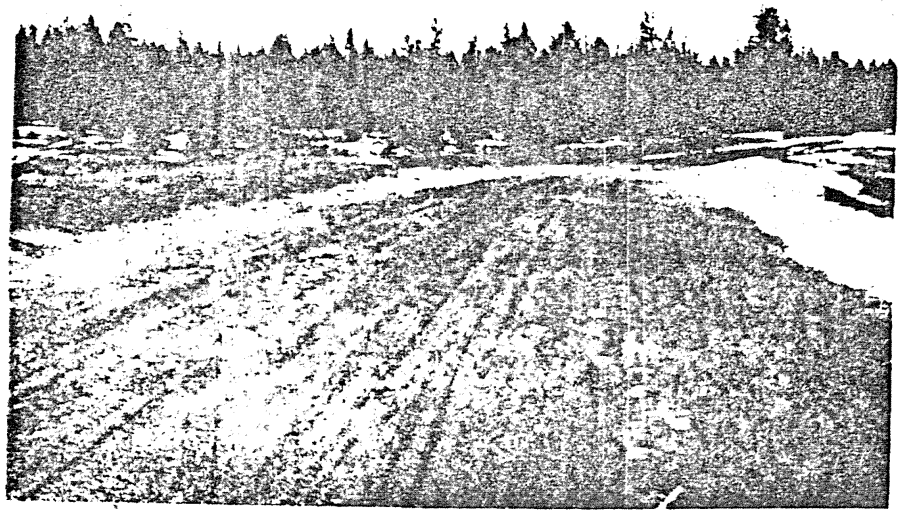

FIGURE 26. Contrast between untreated Section and clay stabilized Section (foreground). Note rutting on untreated Section - February, 1970.

Untreated Sections

These sections behaved like normal pumice roads with no maintenance being attempted since construction. By November washboarding and dusting had developed. No appreciable dusting has been observed on any of the stabilized sections. During the February visit the untreated sections were severely rutted, with much shoving and displacement in the wheel paths. This severe rutting was not noticed on the cement, lime, clay or road mix sections (Figure 26).

Traffic

Originally it was anticipated that the test road would experience traffic from a timber sale. However, by February the buyer had not exercised his option to proceed. A recording counter was placed on the project 20 September 1969, less than one week after completion of construction. Traffic was light the rest of September, with less than 50 ADT. However, hunting season began the first weekend in October and the ADT went as high as 378 ADT during this month. In November the traffic had returned to normal with less than 30 ADT. On November 20, 1969, the counter was removed in anticipation of closure due to winter snow. By this date approximately 3800 axles had traveled the project, the majority being recreational vehicles. From November to the last visit in February 1970, it is estimated very little traffic used the road as there was still snow on the ground.

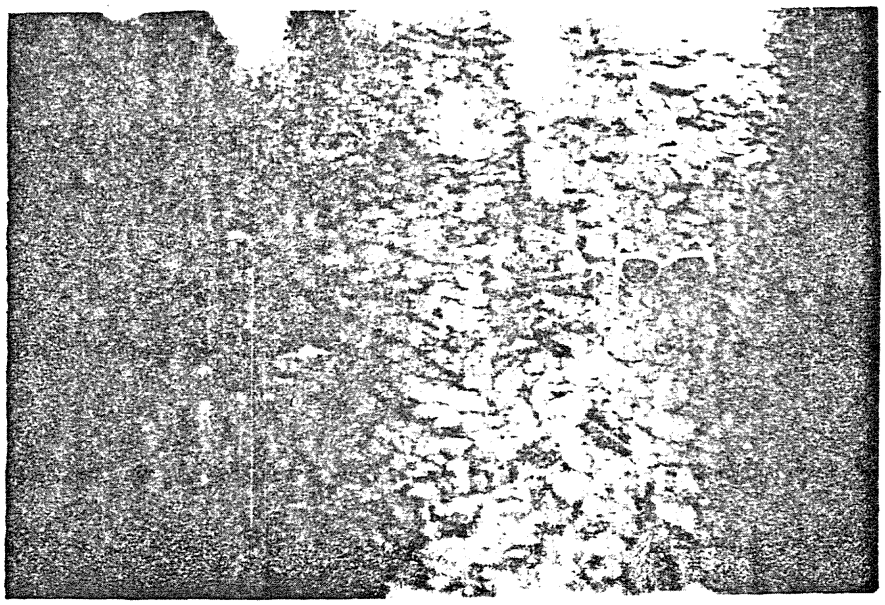

FIGURE 25. 1.1 gal/sy BS-120 Penetration Section approximately 6 months after Construction

FIGURE 26. Contrast between untreated Section and clay stabilized Section (foreground). Note rutting on untreated Section - February, 1970.

DISCUSSION AND CONCLUSIONS

Due to the lack of compaction equipment, especially of a vibratory type, no definite conclusions can be reached concerning the most efficient method of achieving density in pumice soils. With the 20 ton rubber-tired compactor used on the testroad, no apparent increase in density was noticed (see Appendix D, Field Density Results). The treated sections all increased in density, cement the least(though this may be the result of freezing and loss of density the night after the cement section was constructe In the lime, clay and road mix sections the density increased about 1/3 over the original (60 to 80 pcf). This is the result of better densification and filling of voids. These sections were originally scarified and mixed to a depth of 6 inches; however, final compacted thickness was about 4 inches, or a reduction in volume of about 1/3.

Recommendations on compaction based on field observation and the Guatemala study (12)suggest that standard compaction controls are difficult to apply (i.e., AASHO Test Methods T-99 and T-180) due to degradation, lack of binder, and the difficulty of obtaining a smooth compaction curve (Appendix E). It is felt a more suitable control technique would be to base compaction on relative density:

$$RD = \frac{e_{max} - e}{e_{max} - e_{min}} \times 100\%$$

Where:

e_{max} = maximum void ratio possible;

e_{min} = minimum void ratio possible; and

e = tested field void ratio.

Values of less than 50% are considered loose. A value of 70 or 80% would then be recommended and probably could best be achieved by a vibratory compactor.

The clay section appeared to be the stabilized section that performed the best from a dusting, riding surface and maintenance point of view. One main advantage is that the material can be scarified, bladed or recompacted at any time distress develops, which is not the case with the lime, cement or roadmix sections. Cost in most cases can be reduced by the use of local material. The main problem becomes locating the sites of clay deposits in areas covered with a pumice deposit. Often clay can be found in cinder pits in the form of weathered cinders. The Soil Conservation Service could be of great assistance here in locating clay sources on their maps.

The asphaltic penetration treatment sections appeared to be the least satisfactory of all the stabilizing methods. This primarily results from the lack of bonding between the penetrated area and the loose pumice below. A shear plane develops, together with high deflections, causing cracking failures. The penetrated thickness acts like a structural section, which is too thin to support the imposed loads. In addition, during spring thaw (as observed in February), water collects just below the penetration causing soft spots and low bearing values. Based on observations during the late spring of 1970, it was observed that failure was also due to lack of curing of the heavier penetration treatments even at this late date.

The lime treated section appeared to be the best of those prepared from commercial products. The main advantage on this test road was the ability to be recompacted after the "fluffing" from night time freezing. The cementing action that was achieved with the lime was surprising, especially with the coarse grained pumice on the project. Based on literature review of the experience of others, it was thought that only fine grained

pumice would produce adequate cementing action (19). It may be due to the cementing material caused by the nuee ardente deposit. It is unknown at this time how the lime stabilized area will behave under repeated freeze thaw, or through several winter seasons.

The cement section did not behave as well as the lime treated section, mainly because of the detrimental freezing that occurred after construction. In addition, the pumice had a high organic content from roots and other vegetation, which probably prevented complete hydration of all the cement. This could probably be reduced with the addition of a small percentage of calcium chloride. If the freezing action and organic material were not present, most likely the cement section would have performed as well as the lime section.

The road mix section appeared initially to perform quite well; however, the lack of curing with depth which became apparent in February makes it less desirable. This lack of curing was due to the late construction season and the low temperatures during the winter. The partial curing produced soft spots and wheel path rutting in this section. Other types of asphaltic material that might cure more rapidly more than likely would present problems in mixing and coating of the pumice as was experienced in the laboratory testing.

There appeared to be little benefit from using a penetration on the lime and cement treated sections. In both cases this treatment (at 0.3 and 0.4 gals/sy respectively) had disintegrated into small pieces, especially in the center section of the roadway. Observations this past fall showed very little dusting on the lime and cement sections without

the penetration treatment; however, according to others (20),(21), dusting is a problem without a surface treatment. It is hoped that more detailed observations this coming summer will determine the importance of this problem in pumice soils.

Economics of Stabilization

Due to the limited nature of the test road and the resulting inefficiency of construction, the relative costs for each stabilizer were very high. A summary of the cost is as follows:(using Forest Service equipment and forces - not including overhead)

Stabilizer	Total Cost	Cost Per Cubic Yard	Cost Per Square Yard
Clay	$212	$24.00	$ 4.00
Cement	400	30.40	7.40
Lime	560	62.40	10.40
Roadmix (BS-120)	710	79.20	13.20
Penetration	590	-	$ 0.09 @ 0.3 gal/sy 0.30 @ 1.0 gal/sy 0.48 @ 1.6 gal/sy

The costs experienced for the commercially prepared materials were unusually high as premium prices were paid for small quantities. Checking with manufacturers in the Portland area revealed that a substantial reduction could be obtained when buying in large bulk quantities (i.e., more than 100,000 lbs). The following costs are based on the reduced prices assuming a major project to be constructed (i.e., more than 2 miles of road construction)

Assuming a job 75 miles from Klamath Falls(5 miles on back roads) the bulk costs would be:

Lime: $29.90 per ton + freight = $36.85 per ton
Cement: 28.90 per ton + freight = 35.85 per ton
BS-120: 28.00 per ton + freight and spreading = 55.50 per ton
Clay: (assuming a Forest Service pit approximately 12 miles from the project) = 2.50 per ton

Estimating that a 3000 feet by 24 feet wide by 6 inch deep section stabilized roadway could be constructed per day using: 2 graders, 1 roller, 1 water truck, 4 operators and 1 laborer, this would be approximately $400 per eight-hour day(including 25% for overhead and other fixed costs). Adding the same fixed cost of 25% to the material prices, the following costs would result:

Stabilizer	% By Weight	Material Cost/sy	Labor Cost/sy	Total Cost/sy	Total Cost/cy
Clay	20%	$0.08	$ 0.05	$0.13	$0.78
Cement	5%	0.30	0.05	0.35	2.10
Lime	5%	0.31	0.05	0.36	2.16
Asphalt	15%	1.41	0.05	1.46	8.76

These prices would be approximately the same using Forest Service forces or construction by contract.

Conclusion

All evidence points to clay stabilization as being the most practical and economic method to stabilize pumice. From a practical use, it can be later maintained and rebuilt without destroying the properties of the binder. It costs about half of the most common commercial stabilizers, cement and lime. Several questions need to be answered before clay is accepted as a solution to the pumice surface road problem -- First, what is the minimum percentage that can be used and still be effective as related to the PI and LL of the clay; and, second, what is the availability of clay sources in pumice areas. These questions can only be answered by field investigations and testing perhaps under actual loggin traffic.

If such additional test sections are used, the use of vibratory compactors with relative density for control should be investigated. Also, the use of lime in smaller percentages should be investigated as this metho of stabilization also has promise. However, the results will probably vary as the pumice type and the gradation varies.

Asphaltic mixes should be avoided, unless a sufficient structural section can be built up over time so as to have adequate coating and curing. The use of dust oil is felt to be of little value, especially if only applied once or twice.

Cement is probably an adequate stabilizer; however, effects of organic material, which is common in pumice soil, makes it less desirable than lime

Recognition should go to the persons on the Winema National Forest who made this project successful: Tom Kerns, Forest Engineer; Doug Hatch, Road Management Assistant; Art Frey, Chemult District Engineer; Gid Parker and the C & M Crew.

Future study should investigate the use of pumice as a stabilized base under an asphaltic wearing surface. Stabilizing with lime or cement (possibly as low as 2% by weight) would reduce the high resiliency of the pumice thus preventing surface cracking of the asphaltic wearing surface. The asphaltic wearing surface could be a multiple chip seal (armor coat) applied over a period of time, a road mix of cinders, or a plant mix of cinder. The construction should be started in the early summer so as to allow the lime or cement to cure adequately to resist frost action in the fall and winter.

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A P P E N D I X

APPENDIX A
Sample Profile of Pumice Deposit on Test Road

Station 30+00 on Bear Flat Road just south of #286H spur.

Depth	Description
0 - 8"	Gray-brown, fine grained, organic pumice with many roots;
8"-14"	Yellow-brown, coarse grained pumice (fine gravel size);
14"-24"	White, sand sized pumice;
24"-27"	White-brown, fine gravel size pumice;
27"-30"	Gray, fine sand size particles (probably basalt alluvium of the Collier Series)
30"-40"	White, coarse sand size to fine gravel size pumice

The pumice soils in this area are of the Lapine-Shanahan Series. These are in general described as follows(18):

Lapine Series: Very coarse pumice sands; thin, weak A_1 horizons; Regosols in "Western" Brown Forest Soils Zone.

Shanahan Series: Moderately coarse pumice sands; weak A_1 horizons; Regosols in "Western" Brown Forest Soil Zone.

Specifically, the Lapine Series mineralogically is a pumice which is glassy hypersthene-augite dacite with accessory hornblende. The surface of the mantles, the A_1 or humus mineral horizon, appears to be consistently finer texture than all succeeding horizons below the surface. This can be accoun for by the final fall-out of ash which has the lowest relative mass per unit of surface area (18).

A detailed profile description is as follows(3):

> "This soil (Lapine Series) has a loamy coarse sand A_1 horizon averaging about 2 inches in thickness and having a fairly high organic matter content. The AC horizon is also a loamy coarse sand but usually has a relatively high content (20 to 30 percent) of pumice gravels. It varies in thickness from 5 to 13 inches. The C_1

horizon is a coarse gravelly sand with pumice gravels making up from 50 to 70 percent by weight of the horizon. It varies in thickness from 3 to 36 inches. The coarse sand C_2 horizon varies in thickness from 7 to 36 inches. The gravel content of the C_2 varies from 15 to 30 percent. The fresh pumice of the Lapine series is underlain by bedrock or older soils ranging from sandy loam to clay loam in texture.

APPENDIX B

Laboratory Test Procedures

All unconfined compression tests were performed on 2-inch diameter by 4-inch long specimens compacted under static compression of approximately 700 psi. Natural pumice mixed at optimum moisture content (40% by dry weight) obtained a dry density equal to the maximum dry density as determined by AASHO Test Method T-99 when compacted under the above pressure (approximately 60 pcf). The compaction mold was constructed so that compaction was applied to both ends of the specimen by loading heads. The mixing and compacting procedure for each additive are summarized below.

Natural Pumice

1. Air dry material.
2. Add water and mix to obtain optimum moisture content (40%).
3. Lightly rod sample into mold using three layers.
4. Compact under static compression to 700 psi using hydraulic test machine (load rate at approximately 0.05 inches per minute).
5. Hold sample under pressure in mold for approximately 1 minute to allow for plastic adjustment of particles.
6. Extrude sample from mold and weigh.
7. Cure half of specimens in air for 7 days, the other half in a humid cure tank for 7 days.
8. Test in unconfined compression at a loading rate of 0.05 inches per minute.
9. Record maximum load obtained.

Cement

1. Through 6 same as for natural pumice, except that cement is added (Type II) during step 2, as a percentage of dry weight.
7. Cure all specimens in humid cure tank for 7 days.
8. Remove from humid cure and soak half of specimens for 1 hour prior to testing.
9. Test in unconfined compression at a loading rate of 0.05 inches per minute.
10. Record maximum load obtained.

Laboratory Test Procedures

Lime

1. Through 6 same as for natural pumice, except that hydrated lime is added (miracle lime) during step 2, as a percentage of dry weight, and the mixture is cured in a sealed container for 4 hours before compaction.

7. Place all specimens in a sealed container and cure in an oven at 140° F. for 7 days.

8. Remove from oven, allow specimens to cool and then soak half of specimens for 1 hour prior to testing.

9. Test in unconfined compression at a loading rate of 0.05 inches per minute.

10. Record maximum load obtained.

Asphaltic Material

1. Through 6 same as for natural pumice, except that the moisture content for the BS-120 was 5% (as recommended in Reference 16), and the SS-k mixed with 20% and 5% moisture. There appeared to be little difference in ease of mixing.

7. Cured half of specimens in air for 7 days, the other half in air for 7 days (until cured to constant weight) and then soaked for 7 days (as recommended in Reference 17).

8. Test in unconfined compression at a loading rate of 0.05 inches per minute.

9. Record maximum load obtained.

Cinder Clay

1. Procedure the same as for natural pumice, except that clay is added in step 2, as a percentage of dry weight.

APPENDIX C

Laboratory Test Results

All results are based on unconfined tests, the maximum load being reported.

Plain Pumice

28 psi moisture cure (humid)
59 psi dry cure (air)

Type II Cement

0%	2%	5%	10%	
0 psi*	57 psi	167psi	177 psi	soaked 1 hr before te
28	108	129	166	not soaked

Hydrated Lime

0%	2%	5%	10%	
0*	25	137	336	soaked 1 hr before testing
28	35	134	354	not soaked

Cinder Clay

0%	10%	20%	30%	
28	24	24	26	moist cure(humid)
59	96	110	151	dry cure (air)

BS-120

0%	10%	15%	20%	
0*	41	18	14	soaked for 7 days
59	76	47	29	air cured
-	1.8	2.6	2.1	ratio of strengths**

SS-k

0%	15%	20%	30%	
0*	0*	38	66	soaked for 7 days
59	74	31	43	air cured
-	-	0.8	0.7	ratio of strengths**

* Sample disintegrated upon soaking

** The peak ratio is recommended as the most desirable percentage of additive for asphaltic materials (17).

APPENDIX D

Field Density Results

1.1 In place field density before compaction and stabilization (2 Sep 69).

Sta 8 + 30f	*55.4 pcf @ 12.5% moisture	(coarse pumice)
Sta 11 + 90	54.5 pcf @ 12.5% moisture	(coarse pumice)
Sta 14 + 00	60.3 pcf @ 13.5% moisture	(coarse pumice)
Sta 23 + 40	65.5 pcf @ 11.5% moisture	(fine grained top soil)

II. In place field density after compaction and stabilization (9 Sep 69).

Sta 7 + 90	64.8 pcf @ 13.8% moisture	(4 inch thick cemen treated section)
Sta 11 + 90	49.4 pcf @ 16.5% moisture	(untreated -compact only)
Sta 14 + 20	77.9 pcf @ 14.0% moisture	(6 inch thick clay treated section)
Sta 22 + 90	79.2 pcf @ 12.0% moisture	(4 inch thick lime treated section)
Sta 30 + 05	**98.5 pcf with asphalt	(4 inch thick road mix section)

Notes: Maximum density and optimum moisture content by AASHO Test Method T-99 is approximately 60 pcf and 40% moisture

* All densities are calculated based on dry weight

**Based on wet weight as no estimate of moisture or volatiles was made

APPENDIX E

COMPACTION TEST RESULTS
(Summary of a report by Alex Mitchell and Chris Schwarzhoff, Regional Materials Laboratory, Portland, May 1970)

Pumice Compaction

Compaction tests were performed on pumice from the Bear Flat Road. Material from Station 30+00 was soaked overnight and then compacted using new material for each point. The effect of degradation was then checked by obtaining a second and third compaction curve using the material of the previous compactions. The following results were obtained:

	Max. Density	Opt. Moist.
First compaction	42.6 pct	74.4%
Second compaction	45.9 pct	73.5%
Third compaction	56.2 pct	61.5%

Examination of all three curves indicated another hump of higher density probably exists at a moisture content less than that tested. However, due to a lack of material, it was not possible to extend the testing into this zone. Using modified compaction (AASHO T-180), a maximum density of 59.8 pc and optimum moisture of 54.4% was obtained.

A second series of compaction tests were performed on a mixture of pumice from station 30+00 and Station 8+00. Using AASHO T-99, the following results were obtained:

	Max. Density	Opt. Moist.
First Compaction	38.2 pct	46.2 %
Second Compaction	41.6 pct	46.5%
AASHO T-180	47.7 pct	54.0%

The T-180 test results appear to be from the second hump on the compaction curve.

Pumice-Clay Mixture

A sample was obtained from the pumice-clay stabilized section (Sta. 13+00 to Sta. 15+00) on the test road. A CBR of 26.9 was obtained at 95% of maximum density. The liquid limit of the clay was 35 and the plastic index was 7. The mixture of 70% pumice and 30% clay was nonplastic.

Asphalt Stabilization

A sample of the BS-120 stabilized road mix was obtained from the test road. Marshall stability tests were performed on the material using 25 blows on each end. An average value was found to be 366 pounds at a flow value of 13. A centrifuge extraction test was performed on the material which showed the asphalt content to be 15%.

Gradation

The following results were obtained from mechanical analysis:

% Passing	Pumice Sta 30+00	Pumice Sta 8+00	Cinder Clay	70% Pumice 30% Clay
1"	100	100	100	100
3/4"	99	100	97	99
1/2"	97	100	92	96
3/8"	93	99	86	93
#4	77	88	73	88
#10	51	54	60	78
#40	26	12	47	53
#200	14.1	5.8	29.6	13.3

OPENING COMMENTS AND INTRODUCTION OF PANEL MEMBERS

By
Tom M. Kerns

There have been very few scientific studies made on volcanic materials for road building. Most of the skills of the trade have been developed through trial and error of construction people. Unfortunately, much of this skill is inside the mind of the individual without a means of passing it on to others.

With this in mind, this afternoon is devoted to construction people, with the thought being to find out techniques they have tried and found successful and, just as important, things they have tried which didn't work. I say just as important since others may try the same thing if we can't draw on their experience.

I don't doubt there are others in the group today who have as much experience and knowledge as the panel members. In selection of the panel it was not intended to slight anyone. We selected the panel based on our knowledge of people who had something to contribute, and I'm sure many of you will also have something to contribute when we come to the discussion period.

I would like you to hold your questions until the second half of this panel discussion and, since we will have a break between the first and second half, I will pass out cards for your use so you can write the questions down as they come up and not forget them.

The information given by the panel will be published in the proceedings, and the Question and Answer session will also be available if important items are brought out.

Our panel consists of 5 people -- 2 County Engineers, 2 logging industry people, and 1 Forest Service individual.

Our first speaker is a County Engineer from Lassen County, California. He has worked for Lassen County for 24 years, with 15 years of this being as Road Commissioner responsible for construction and maintenance of County roads and bridges.

He has held several offices. From 1958 to the present, he has been the Executive Secretary of Northern California County Engineers' Association, and for the same period Chairman of the Board of Review for California County Route Marker Program.

In 1963 and 1964 he was President of California County Engineers' Association of California. From 1965 through 1967, he was Western Regional Vice-President, National Association of County Engineers, and in 1967 and 1968, he was President of the National Association of County Engineers.

With this send-off, I'll give you Bill McIntosh, Lassen County Road Commissioner:

THE USE OF VOLCANIC CINDERS IN COUNTY ROAD CONSTRUCTION & MAINTENANCE

By

William D. McIntosh

Lassen County Road Commissioner

Presented at the

Workshop on Low Class Road Construction Using Volcanic Cinders & Pumice

at

Klamath Falls, Oregon

October 5, 1970

THE USE OF VOLCANIC CINDERS IN COUNTY ROAD CONSTRUCTION & MAINTENANCE

John Lund called me sometime back to ask if I would be available to discuss the use of cinders on county roads at this meeting in Klamath Falls. I received his request with mixed emotions - sort of like watching your mother-in-law drive over a cliff - in your brand new Cadillac. While I was very pleased to have the opportunity to meet with you fellows and to enjoy the sights in the Klamath Falls area - I was at the same time a little concerned that I may have over-stepped the bounds of my expertise. We have used cinders for many applications in Lassen County in the past several years however, and I will attempt to tell you what I know of their value and use on county roads. I asked our Road Superintendent for his opinion of cinders as a road material and he told me, "They're the best material you can get - if nothing else is available"! Actually we don't think they are all that bad, but they are rather critical to handle and we have lots of respect for them for that reason.

In our part of the country, there are wide varieties of cinders, ranging from a very clean, dry, pourous aggregate; to almost rock hard "heavy" cinders; to gravelly type with considerable fines in them; to those with a very high clay content. If we could have some of each throughout the county, we could design our work accordingly. Unfortunately, however, they are located in such a manner that we have to use what we have, where we have them, and as best we can to suit conditions and to get the job done.

In Lassen County, we use cinders for the following purposes: (1) as a gravel surface, (2) for sub-base and select base aggregate, (3) for road mixed surfacing, mixed with liquid asphalt, (4) for seal coating paved roads, and (5) for sanding on snow and ice.

I will discuss each application briefly, describe how we use them and try to give you a general idea of the results we get in each case.

First, and probably the simplest, (and incidentally, one of the best applications) is for a gravel surface on a low class county road. For this purpose we try to find a cinder that contains sufficient fines in the grading to bind them together. For an open surface road we even like a certain amount of clay, as that tends to hold them together even after extended dry spells (which incidentally we experience every summer - all summer). We find that the drier or "popcorn" type cinder is very poor for this purpose as they separate on the road, rut and washboard to the extent of rendering them almost useless as a gravel surface. They are also extremely hard on tires. If the popcorn type cinder is all that is available, we find it beneficial to incorporate native dirt or sand with them as a binder. This is not considered good road building practice, but it does get the job done where there is no other answer without going beyond the bounds of reason in the expenditure of road funds. Cinders as you know are highly abrasive and therefore should be bound together as much as possible when used in the open for a gravel surface. For the best results the cinders should be watered and rolled when they are placed on the road. Many times however, that is not possible to do for a variety of reasons, the most common of which is the lack of watering and compacting equipment. If we are fortunate to be removing cinders during a time of the year when they are wet, or at least damp, we try to take advantage of that condition by spreading them as we go and using our dump trucks as compactors. We find we can save considerable time and money in many instances by taking a little extra care in spreading the cinders as they are placed on the road and taking care to lay them to the proper grade and cross section. The truck drivers are instructed to stagger their tracks in such a way as to cover the entire width of the roadway. In that way we have a nearly completed gravelled road, well shaped and compacted by the time we get to the end of the haul.

The second application I mentioned was for use as sub-base and select base

material under a paved surface. This is one time we do not want to have very much clay in the aggregate as any material with a sand equivalent of under 30 is not suitable as a base material. Clay, as you know, swells when it gets wet and if there is enough clay in the base it will cause the pavement on top to heave and break up. We are, therefore, very careful to see that cinders used for sub-base and base are tested to determine the clay content as well as the other factors, such as "R" Value, grading, etc. Unlike the method I just described for a gravelled surface, projects on which we are applying a sub-base or select base are generally a higher type road that requires more attention to depth, grade, cross section and compaction. It is therefore necessary to have the proper equipment on hand to lay the cinders, shape them, apply water and compact them. One of the major problems we encounter in the use of cinders for select base is getting the proper compaction and holding it until the surfacing is applied. It is not uncommon to get 110 - 115% relative compaction on a cinder base. In many cases however, as soon as the water leaves, the compaction goes with it. The only solution to that problem that we have come up with thus far in our experience, is to schedule a prime coat as soon as the base is dry enough to accept liquid asphalt. For these reasons I'm sure you can understand why we are not particularly thrilled with having to use cinders for select base applications. They are however, completely acceptable for that purpose, and as I said earlier, when nothing else is available without exhorbitant costs, we of course, use them. I might add we use cinders for this purpose to a considerable extent as Greg Margeson of the Lassen National Forest can attest.

The third application I mentioned was for use as a road-mixed surfacing. Here again we do not particularly like to use cinders, but when that is the only material available, we have no choice other than to go to outrageously high costs by importing, or setting up a crushing operation or quarry site. The dry, pourous characteristic of cinders adds to the cost of road mixing due to the additional liquid asphalt required. A normal road aggregate generally requires about 5 - 6-1/2% of asphalt to make a mix. Cinders, on the other hand, will run from 9% to as high as 13%. The

grading, sand equivalent, etc. must, of course meet the required specifications. Here again, it is necessary to weigh the cost of one method against the other - in this case the difference between the cost of additional asphalt against the cost of importing for a long distance, setting up a crusher or whatever. Road mixing is unquestionably the most critical and frustrating use of cinders we have ever encountered. In our line of work we learn to rely pretty heavily on the "eye-ball method" as a check on the quantity of asphalt we use. With cinders however, the looks of the mix while you are in the process of making it is totally different from that of a regular road mix aggregate. With normal aggregate you look for all the particles to be coated and black but not shiney. With cinders, if you stop at that point, you will find that the mix is too lean and will ravel on you. Therefore, even though it looks wrong and too rich, you must add the right amount of asphalt or it just won't work. I personally don't even like to look any more. We have a few men who are very capable of controlling the asphalt contents and I prefer to leave that particular phase to them without my nervous presence. A road mixed surfacing job when properly done is completely acceptable however, and well worth the wear and tear on the nervous system as well as the savings in costs. There is at least one advantage in the use of cinders for road mixed surfacing and that is that the asphalt quantities on the high side are not as critical as they are with ordinary road mix aggregates. A little too much asphalt with ordinary aggregate will almost always result in a mix that is too rich and will wrinkle and shift on the road. A little more than the planned amount of asphalt in a cinder road mix is generally absorbed without detrimental effect.

We have also discovered through trial and error that we get the best results in cinder road mixes using medium curing asphalt rather than a slow curing product. We have found that the base asphalt contained in the medium curing grades is a much harder and more stable asphalt. It makes a stronger mix, that stays in place in a far superior manner to the residual asphalt found in the slow curing grades.

The fourth use of cinders is for seal coating of paved surfaces. For this application the material is not as critical as it is for base or road mixed surfacing. It is necessary however, to have an evenly graded cinder aggregate that will flow through a chip spreader or seal coating machine. The only critical point in cinder sealing in my opinion, is the same as you would find in any type of seal coating operation. It just simply must be done properly or you will end up with a lousy job. Red cinders in particular make for an aesthetically pleasing road surface if they are applied properly so that the road is not red streaked, but is completely red in color. We like to use cinders for seal coating, but as luck would have it, we have very few places in Lassen County where it is not easier and cheaper to use sand or rock chips for this purpose.

The last application mentioned was ice control. Cinders are an excellent material for ice control, due to their abrasive nature. There really isn't much to add here other than to state that many road and highway departments use cinders to sand icy hills and streets during the winter months. The only concern is that they are screened to a size small enough to pass easily through a sand spreading attachment on a dump truck, and are kept dry enough to pass through the machine without clinging together and clogging the sand spreader. Ice control is a very necessary and very important function of any road maintenance agency, and while we do not do a great deal of it in Lassen County we do recognize the need for a suitable material for that purpose. We realize the value of cinders on ice, and this is one type of work on which we <u>prefer</u> them to other aggregates.

In conclusion, I would summarize my thoughts on the five uses of cinders I have discussed here as follows:

(1) <u>For a gravel surface</u>: We like some types of cinders for use as gravel, particularly those that have sufficient fines and enough clay content to bind them together and hold the shape for extended periods of time.

(2) For sub-base and select base: Though it is difficult to find a cinder aggregate that will compact and hold its compaction, while at the same time being a high enough quality to meet the specifications for select base - we do use them extensively and can tolerate the accompanying problems.

(3) For road mixed surfacing: When the cost factors dictate the use of cinders for road mixing we will, and do use them. The use of the right type of liquid asphalt as well as good weather conditions, optimum asphalt content and good luck, play an important role in the success of a cinder road mixed surfacing. We don't like it, but do use it and will continue to do so.

(4) For seal coating: A highly satisfactory product for seal coating - one which we like and use whenever and wherever possible.

(5) For ice control: We feel that cinders are a superior product for ice control and would prefer them to sand or screened rock.

As a general concluding statement, I would say that cinders are like women in many ways - it's hard to live with them and we can't live without them!

Our next speaker is a representative of Weyerhaeuser Company. He received a Degree in Forest Management from Iowa State University in 1960, followed by 2 years with the Army. At the end of his Army career in 1962, he came to Oregon with the Forest Service. After a brief tour with the Forest Service, he went to work for Weyerhaeuser in September of 1963, and since 1966 he has worked with Weyerhaeuser's road program.

He informs me his presentation is not meant to be any kind of a technical paper concerning road construction or surfacing, but a review of past and current local Company practices in road construction and their brief experimentation in dust abatement. Lyle, this sounds like just what we are looking for, so I'll now turn the floor over to Lyle Ficken of Weyerhaeuser Co.:

October 5, 1970

ROAD CONSTRUCTION PROBLEMS AND SOLUTIONS ATTEMPTED USING VOLCANIC CINDERS

WEYERHAEUSER COMPANY

BY Lyle Ficken

ROAD SURFACING EXPERIENCE BY WEYERHAEUSER COMPANY - KLAMATH FALLS BRANCH - (CINDER)

HISTORY - Until late 1950's Weyerhaeuser, Klamath Falls, was primarily a railroad logging operation with very minimal road development throughout the tree farm. Upon conversion to complete truck logging, construction of all weather roads became necessary. Prior to this time, winter logging was accomplished strictly by railroad.

The need for surfaced roads became crucial to our logging plans if year round operations were to continue. Some cinder pits had been developed on Weyerhaeuser ownership and many more areas were prospected and eventually opened revealing vast sources of surfacing material.

Two very important reasons for the initial and continued use of cinder as surface material are (1) abundance of cinder throughout our ownership and (2) relative lower costs as compared to other available alternatives.

CONSTRUCTION PRACTICES - SURFACING -

Presently the majority of our main haul roads and winter logging spurs are cinder surfaced. Initial application usually amounts to 6" - 9" of compacted pit run material watered, bladed and grid-rolled.

Experience has shown us that grid-rolling most of our pit run material eliminates the oversize problem to some extent, but much material is still lost due to the fact that not all pit run cinder is easily broken down in this fashion. We have quite a variance in quality and type of cinder depending on the source of material.

To date, the only instance where we have crushed cinder for surface application has been in our winter logging areas for sanding purposes only. We are investigating more extensive use of crushed cinder as opposed to pit run for future surfacing and resurfacing work.

Our present plans seem to indicate an expanded surfacing program to allow more flexibility in our logging plans. This will definitely require a more thorough knowledge and understanding of cinder as surfacing material on company haul roads.

BENEFITS OF CINDER SURFACING -

As previously mentioned, Weyerhaeuser has an abundance of cinders throughout most of the ownership which allows us the rewarding benefit of a relatively low cost material for road surfacing. This fact, together with the knowledge that over the years, experience has proven cinder to be adequate for all weather road surfacing, explains our extended use of the material.

From the company's standpoint this economic benefit outweighs problems encountered by use of cinder surfacing.

PROBLEMS ENCOUNTERED USING CINDER SURFACING -

The problems we've experienced with cinder refer to pit run material. As previously mentioned, our use of crushed cinder has been limited to date. Probably high on our list of difficulties, if not first, is the excessive maintenance costs incurred due to the tendency of cinder to "washboard," requiring constant blading and watering. The word "adequate" should precede watering if you are to obtain the properly maintained cinder road; however, this becomes nearly impossible during hot, dry weather. Our figures "indicate" watering costs in the neighborhood of $1,500.00 per mile per season which still may not give adequate results in some cases. Nevertheless, watering expenditures still exceed those of blading.

Use of strictly pit run cinder has created problems in some areas because of excessive oversize material which does not break up with grid-rolling. This is actually a two-fold problem: (a) ditches are filled with the oversize upon blading, and (b) surfacing costs are increased by hauling of this unusable material. Oversize cannot all be removed from the surfacing and may cause future maintenance problems. Lack of fines in some of our pit run material leads to poor compaction, originally. However, with continued use of a road consisting of said material, fines are generated eventually.

Erosion can be a greater problem with this type of surfacing due to the light weight of the material and problems in obtaining proper compaction.

Other problems may come to mind, but these are the ones of main concern to us.

SURFACE WEAR TESTS (CINDERS):

An attempt was made by Weyerhaeuser to determine surface wear on cindered roads. The only such project, to date, was initiated during 1960 and terminated three years later in 1962. Our goal was to obtain a rate of surface wear in terms of cinder loss per thousand board feet of haul. Main company haul roads were used as test areas. Tests were conducted in the following manner: (1) holes were dug through the layer of cinder, (2) metal plate was placed in bottom of hole, (3) the surface thickness was then measured and recorded, (4) later the first year the same holes were opened and remeasured, the remaining years two annual measurements were made. After our first remeasurement of the test holes we discovered the thicknesses varied as much as plus or minus one inch. This occurred throughout the three-year test period. Apparently blading of the road created

the variance which led to inconclusive evidence of the exact amount of surface wear. However, after the three year period, in which Weyerhaeuser hauled in excess of 200 MM b.f. of volume over the test road a plus or minus one inch variance still persisted.

The particular road tested was concidered adequately maintained because it was a relatively short stretch of main haul road receiving sufficient blading and watering at all times.

The results did reveal to us that a well maintained cinder road actually experienced for less surface loss than anticipated with such a great amount of use.

Intensive maintenance may be reasonable with large volumes using short mileage, but the difficulties arise when you try to keep costs from becoming exorbitant and yet do an adequate maintenance job where a long haul route is involved.

DUST ABATEMENT ATTEMPTS ON CINDER SURFACE ROADS

REASONS FOR DUST ABATEMENT ATTEMPTS -

As previously mentioned, our maintenance experience has shown that watering costs can be more than 50% of our expenditures during times when it becomes necessary. Several years ago Weyerhaeuser decided to experiment with oil as a dust abatement in order to: (1) lower maintenance costs, (2) prevent excessive surface loss, and (3) create safer hauling conditions. Experimentation has occurred spasmodically since the initial attempt.

WEYERHAEUSER COMPANY DUST-OIL EXPERIMENTATION -

Beginning with our first recorded attempt and following through to the present our experience with dust-oil is as follows:

1. 1964 - 8.00 miles of company truck road from our mill west was prepared for dust-oil application. Log hauling had commenced at least one month prior to the application. Normal blading, shaping and watering preceded the oiling and apparently road preparation was acceptable. All eight miles were surfaced with cinder.

   For this program the road was segmented and three different oils were used: (1) Compak Oil (all petroleum products) - Com-Pak Road Oil Engineering, Fresno, California, (2) Alvisite (all petroleum product) - Com-Pak Road Oil Engineering, Fresno, California, and (3) PS 300 - Western Oil & Burner Company, Klamath Falls, Oregon.

   The costs for each oil tried were:

   1. PS 300 - 12 ft. width, 0.5 gal./sq. yd., $423.36/mile.
   2. Com Pak - 12 ft. width, 0.5 gal./sq. yd., $564.48/mile.
   3. Alvisite - 12 ft. width, 0.5 gal./sq. yd., $441.00/mile.

Conclusions indicate that Compak Oil was most favorable, Alvisite second, and PS 300 a poor third. It was decided, however, that all three oils became generally too hard and, when the road started pitting, conditions became rapidly worse and would have demanded too much patching. The one favorable comment to be made is that we did not require watering for the remainder of the haul season.

2. 1965 - 9.85 miles of the same truck road were again treated with dust-oil. Prior to application, the previous year's results had to be scarified and bladed. Some haul occurred between the completion of preparation and actual dust-oiling. This time the same 8.0 miles of road, oiled in 1964, were again treated with Com Pak Oil, while the remaining mileage received Industrial Weight Dust Oil (Special Dust Oil - 24 $\pm$ TS) - West Coast Oil Co., Oildale, California. (See Exhibit A for specs.) A width of 12 feet was again used. Variable rates of application were used on the 8.0 miles of road receiving Com Pak oil from 0.1 gal./sq. yd. to 0.5 gal./sq. yd. depending on the residual from the past year. Records do not specifically indicate, but it appears areas previously treated with Com Pak took less oil for the second application. The Special Dust Oil was spread at a rate of 0.5 gal./sq. yd. The total cost per mile for both oils used was $738.17. Our conclusions on this test were of a more favorable nature than the previous year. We experienced more residual from the 1964 test than expected. The Special Dust Oil seemed to be easier to maintain with graders without having to scarify. However, it was believed that better results could have been

obtained by having a burm of fines along the road shoulders to pull back over the fresh oil before allowing traffic on the road.

Once again we experienced pitting which was somewhat less prevalent than in 1964.

3. 1966 - We seem to have misplaced records concerning this year's attempts but once again we oiled 9.85 miles of the same road as in 1965.

This year we used Special Dust-Oil on the entire length of road. Amount of spread again varied depending on residual oil in various road segments.

One conclusion which seems to prevail is that the oil used in this test seemed to be better than all oils tried previously. It gave us a fairly smooth, dust-free, running surface, yet remained pliable for blading purposes.

4. 1970.

   a. After a three year period in which our dust-oil program ceased to exist, we decided on a joint effort with the Fremont National Forest. The first try of 1970 occurred on July 11 and involved 18.5 miles of cindered road from Bly to Dairy Creek (5.5 miles - U. S. F. S. Road 3609, 13 miles - U. S. F. S. Road 3610). All of the road #3610 had been resurfaced in September, 1969, with some heavy log hauling after that date. Road preparation was accomplished by the U. S. F. S. and the entire 18.5 miles was treated with Arcadia Medium Dust-Oil (See Exhibit B for specs) at a rate of 0.5 gal./sq. yd. for widths ranging from 18 - 24 feet. The average cost per mile amounted to

$868.18. Log hauling on these roads did not commence until July 30; however, there was considerable use by light traffic. Prior to our use of the road blading was performed on the total length due to considerable washboarding. Some dusting was also occurring at this time, mainly on the curves. After our hauling started the rough condition re-occurred and dusting increased so that by August 8 we were blading and watering continuously.

On August 8, we re-oiled one mile of road #3610 with Arcadia Dust-Oil at a rate of 0.5 gal./sq. yd. The particular mile which received a second application was a test to ascertain whether we should attempt to re-oil the balance of the original 18.5 miles.

One week after the second application a check of the mile segment showed some breaking up and dusting in spots. We decided at that time, it would not prove economical to treat the remainder of the road with a second application.

There seem to be a number of reasons for less than satisfactory results with this type of oil, all of which are interrelated:

(1) Lack of compaction - new cinder on road, no heavy hauling, lack of fines in surfacing material.

(2) Excessive penetration by oil - lack of compaction.

(3) High absorption quality of cinder.

It appears that a higher concentration of this oil would be necessary to obtain desired results. Our one mile test area already had 1.0 gal./sq. yd. application and did not give adequate results, therefore indicating prohibitive costs with continued use of Arcadio Dust-Oil.

The 5.5 miles of road number 3609 did not have new surfacing, did have better compaction, received 0.6 gal./sq. yd. but also proved unsatisfactory.

One important factor which did prevail during the oil application was ideal weather conditions.

b. On September 19 we tested SC 250 dust-oil, Witco Chemical - (see Exhibit C) on 1.7 miles of U. S. F. S. road #3610 which had been previously treated with Arcadia. The road preparations consisted of blading, watering and a burm of fines windrowed along each shoulder. A rate of 0.6 gal./sq. yd. was applied to the entire length at widths ranging from 18-24 feet. Cost per mile was $849.41.

The fines were immediately bladed over the oil. In performing this work it was necessary to block up a front wheel of the grader preventing oil from being picked up by the tire.

WEYERHAEUSER COMPANY RECOMMENDATIONS AND FUTURE PLANS FOR DUST-OILING -

Our experience to date has not been on a continuous basis nor extensive enough to make any specific recommendations at this time. However, of all products we have personally tried, the West Coast Oil Company Special Dust-Oil appears to be the most satisfactory. The latest test using SC 250 is too recent for an accurate evaluation.

If Weyerhaeuser can prove that use of dust-oil will alleviate maintenance costs incurred by watering, then we may consider a continuous dust-oil program. This is not the only factor to be considered. Effects on other maintenance items, including that of equipment, must be weighed in order to make a logical decision.

SUMMARY

All of the preceding comments concerning cinder surfacing and dust-oil must be qualified with the observation that cinder quality varies extremely, at times, depending on the source. Therefore, treatment of cinder may differ greatly concerning surfacing techniques and type of dust-oil used.

We will surface more road with cinder, from now on, in order to obtain flexibility in our logging plans through all-weather roads. However, even with the surfaced roads at present, there must be methods of reducing maintenance costs while improving and/or maintaining the quality. Our dust-abatement attempts are directed toward this goal. Once the right oils are found for the variety of cinder surfacing experienced on our roads, we feel this will be accomplished.

ROAD SPECIFICATION NO. 568 - DUST OIL

1. Description

Initial application of dust oil to control surface dusting is a construction item.

2. Materials

a. The grade to be used, the total amount to be applied and the rate of application is shown on Plans or on Materials List.

b. The dust oil shall be a mixture of asphaltic petroleum products blended to meet one of the following grades:

TEST	TEST METHOD	GRADE SPECIFICATIONS LIGHT	MEDIUM	HEAVY
Flash Point, Pensky-Martens °F Minimum	A.S.T.M. D93	275	275	275
Kinematic Viscosity @ 140°F	A.S.T.M. 12170	70-140	150-200	250-300
Total Distillate to 550° F Max.	A.S.T.M. D402	0-5	0-5	0-5
Asphalt Residue of 100 Pen. % Min.	A.S.T.M. D243-36	40	50	60
Ductility of Asphalt Residue @ 77°F Cm Min.	D113-44	100	100	100
Heptane-Xylene Equiv., % Max.	A.A.S.H.O. T-102	35	35	35
Solubility in CCl_4, % Min.	A.A.S.H.O. T45-45	99	99	99

c. A certified laboratory report covering all items in the specifications must be supplied with each delivery of dust oil.

d. Samples will be secured from the oil distributor and forwarded the same day to the U. S. Forest Service Materials Laboratory for testing. Dust oil not meeting the requirements of this specification will not be approved for payment and the Purchaser will be required to reoil using materials meeting these requirements.

ARCADIA EXHIBIT B

ROAD SPECIFICATION NO. 56 - DUST OIL

1. Description.
   Initial application of dust oil to control surface dusting is a construction item.

2. Materials
   a. The grade to be used, the total amount to be applied and the rate of application is shown on Plans or on Materials List.

   b. The dust oil shall be a mixture of asphaltic petroleum products, blended to meet one of the following grades:

TEST	TEST METHOD	GRADE SPECIFICATION LIGHT	MEDIUM	HEAVY
Flash Point °F., (Open Tag), Min.	A.A.S.H.O. T-79-42	125	125	125
Furol Viscosity @ 100° F., Sec.	ASTM D88	19-35	45-65	70-95
Water, % Max.	ASTM D95	0.5	0.5	0.5
Bitumen Insoluble in Paraffin Naphtha	AASHO T-46-35*	3-6	4-7	5-8
Saturates, % Min. (Oil-Wax Fraction)	**	25	25	25
Total Distillate to 550° F., Max.	ASTM D402***	35	30	30
Residue from Distillation to 550° F				
Furol Viscosity @ 100° F., Sec.	ASTM D88	60-120	150-300	325-650
Solubility in CCl_4, % Min.	AASHO T45-45****	98	98	98

* Except that normal pentane shall be used in place of the 86° to 88° Baume paraffin naphtha.

** Analysis to be made by the method described in Industrial and Engineering Chemistry; Volume 41, Pages 598-608; March 1949; by F.S. Rostler & H.W. Sterrbert.

***Except that the residue remaining after a temperature of 550° F. (instead of 680°F.) shall be used for further testing.

****Ethylene dichloride, dichloroethylene or trichloroethylene may be used as substitute solvents, but carbon tetrachloride is the solvent of the specification.

A certified laboratory report from supplier covering all items in the grade specifications, with the exception of the asphaltene and saturates determinations, must be obtained by Purchaser for the dust oil. Such report must be made available to Forest Service upon request prior to Termination Date.

3. Construction

a. Prior to application the roadbed shall be properly graded, watered, shaped and compacted in conformity with the lines, grades and dimensions of the finished road. Material shall be imported if necessary to secure a satisfactory Traveled Way. Traveled Way shall then be allowed to dry until a moisture content ranging from 2% to 5% in the top two inches is obtained, and about 1/8-inch of loose material is developed either naturally or by scarifying.

b. When more than 1/4-gallon per square yard of Traveled Way is used, oil shall be applied in two equal shots. The second shot shall follow immediately after the preceding shot has penetrated. Application shall be at an air temperature of at least 60° F, when feasible, but never less than 50° F. Oil temperature at time of application shall be not less than 80° F. nor greater than 125° F.

c. Distributor trucks shall be of the pressure type with insulated tanks. The use of gravity distributors will not be permitted. Spray bars shall have a minimum length of eight feet and shall be of the full circulating type with provisions for two-foot extension on each side to cover a greater width when necessary. The header bar shall be adjustable to permit varying height above the surface to be treated. The nozzles attached to the bar shall be either of the conical or flat-slotted type. The distance center to center of the nozzles shall not exceed six inches. The valves shall be operated by levers so that one or all valves may be quickly opened or closed in one operation. Spreading by means of cab controlled valves will be permitted. The valves which control the flow from nozzles shall be of a positive acting design so as to provide a uniform unbroken spread of oil. The distributor shall be equipped with devices and charts to provide for accurate and rapid determination and control of the amount of oil. The spreading equipment shall be so designed and articulated that uniform application of oil, in controlled amounts, may be made by ranging from 0.25 to one gallon per square yard of surface and with a range of pressure from 25 to 75 pounds per square inch.

The distributor shall be equipped with a hose and nozzle attachment to be used for spotting skipped areas and areas inaccessible to the distributor. The distributor also shall be equipped with pressure gauges and an accurate thermometer for determination of temperature of the oil. Distributors and booster tanks shall be maintained to prevent dripping of oil from any part of the equipment. In order to secure uniform distribution at the junction of two applications, the distribution shall be promptly stopped when the uniform flow decreases, indicating the tank is about empty.

4. Measurement

Dust oil placed in accordance with this specification shall be measured in gallons.

Table IV-4—SPECIFICATIONS FOR SLOW-CURING (SC) LIQUID ASPHALTS AND ROAD OILS

CHARACTERISTICS	AASHO Test Method	ASTM Test Method	GRADES			
			SC-70	SC-250	SC-800	SC-3000
Kinematic Viscosity at 140 F, cSt	T 201	D2170	70-140	250-500	800-1600	3000-6000
Flash Point (Cleveland Open Cup), F	T 48	D92	150+	175+	200+	225+
Distillation						
Total Distillate to 680 F, percent by Volume	T 78	D402	10-30	4-20	2-12	5—
Kinematic Viscosity of Residue, 140 F, Stokes	T 201	D2170	4-70	8-100	20-160	40-350
Asphalt Residue of 100 Penetration, percent	T 56	D243	50+	60+	70+	80+
Ductility of 100 Penetration Residue at 77 F, cm	T 51	D113	100+	100+	100+	100+
Solubility in Trichloroethylene, percent	T 44	D2042	99.5+	99.5+	99.5+	99.5+
Water, percent	T 55	D95	0.5—	0.5—	0.5—	0.5—

General Requirement—The material shall not foam when heated to application temperature recommended by The Asphalt Institute.

Note: When the Heptane-Xylene Equivalent Test is specified by the consumer, a negative spot test with 35 percent xylene after 1 hour will be required, AASHO Method T 102.

* See *Specifications for Asphalt Cements and Liquid Asphalts*, SS-2, The Asphalt Institute, for latest revisions.

We have now heard from a County Engineer and a logging industry representative, so I guess our next speaker will be Forest Service. He received a Degree in Engineering from the University of Nevada and has 20 years experience in the field of Materials Engineering in private enterprise and Government service - - Leonard Stern:

ASPHALT TREATED CINDERS

USED ON THE

MEDICINE LAKE ROAD

By

Leonard J. Stern
Materials Engineer
Engineering Materials Investigation Branch
Forest Service
Arcadia, California

MEDICINE LAKE ROAD

MODOC NATIONAL FOREST

ROADWAY MATERIALS TEST SECTION

This roadway materials test project, (7.76 km 4.77 miles) in length, was proposed and designed for the purpose of obtaining data to evaluate the effectiveness, design limitations and economic factors concerned in the treatment of cinder-type materials with numerous bituminous products using in-place mixing and surface penetration methods of surfacing construction.

Throughout the northern area of Region 5 there are extensive accessible sources of various native materials that are available for roadway construction if suitable means for utilization can be determined that fulfill requirements structurally and prove to be economically feasible. Due to the increasing need to provide surface courses on R-5 roadways, all concerned realize we should definitely expand the amount of investigative work being conducted at present in regard to developing possible methods to fully utilize localized native materials including granitic, basaltic and cinder-type materials. The Modoc National Forest is primarily concerned with acceptable methods for using cinder and pumice materials as surfacing and base materials.

The Medicine Lake Road Test Section was constructed during September, 1968. Initially, the work had been scheduled for July 1967, but there was a delay in obtaining project financing which caused further delay in starting the work because of the difficulties encountered in obtaining the required specialized equipment so late in the construction season. Due to these delays, the work did not start until late in the fall and it was then necessary to shut the project down prior to completion because of a heavy, early season snowfall.

The initial project work planning consisted of opening and developing a cinder pit, installing a screening plant, loading and hauling material, blading and compaction of material on the roadbed to a compacted depth of 100 mm (4 inches). At this time it had been planned to apply only one (1) type of bituminous product to the cinder material. The oil product to be used in varied quantities and application methods was the recently developed Bituminous Stabilizer material. When the inclement weather forced a shut down of the project, all work was completed except the application of the bituminous material. During the Spring of 1968, a decision was made by Leonard Stern, EMIB and Russ Schwulst, Forest Engineer to apply numerous types and grades of bituminous products to the cinders instead of using only one oil product as originally planned.

Types and grades of oil to be applied by the in-place road mixing method were Bituminous Stabilizer grades 1000 and 120, SMK and SSK Cationic Emulsions and MC-800 Liquid Asphalt. Bituminous Stabilizer 65 and 120 grades were designated as the materials to be applied by the penetration method.

Work on this project was not resumed until September, 1968, due to Forest workloads and unforeseen problems in securing road mixing equipment. All personnel concerned wanted the in-place mixing accomplished by a Bros cross shaft type mixer but a machine of this make was not available at the time it was needed on this project. Previous investigation and on-site inspection of the Bros Mixer in operation had shown this machine was one of the best in-place mixers for this type of project. A Seaman Cross-Shaft Mixer was finally secured at a reasonable rental cost from an Eastern Oregon County Agency for use on this project. The Seaman Mixer is slower operating, less maneuverable and has rear wheels that travel over the freshly mixed mat causing depressions that often make it difficult to obtain a well-finished surfacing. This mixer also caused some problems during the mixing operations because of the type of oil metering device that was installed on this

particular machine. The metering equipment "plugged-up" easily, especially when using emulsion oils and had to be watched continuously in order that a uniform oil content could be maintained.

The delays of the previous year necessitating a shut-down of the project prior to completion proved to be very costly. The in-place cinder base material was displaced, segregated and contaminated with sub-base soils by spring and summer traffic and required major reconstruction prior to the application of the designated bituminous products. It was necessary to reshape the total roadway area and haul substantial amounts of additional cinder material onto the roadbed to replace cinders lost by traffic erosion while laying in an untreated condition for several months. Although quantities of new cinders were applied to the roadbed, lack of financing prevented the placement of new materials at a sufficient depth so all materials would be completely free of contamination to the total depth treated. The additional project costs for re-establishing a work camp, renting equipment, hauling additional cinders, reblading and compaction of base material amounted to approximately $16,000.00.

The in-place road mixing work was started on September 10, 1968 and, although the daily air temperatures were well within specification ranges, 21°C (70°F) maximum, all concerned hoped for warmer weather during this part of the operation. Mixing procedures consisted of applying bituminous materials to the cinder material at compacted depths of 50 mm (2") and 80 mm (3") with the various oil products applied in quantities ranging from 16% to 20% by dry weight of aggregate.

IN-PLACE MIXING OPERATIONS

Bituminous Stabilizer 120

The first oil product used was BS-120 and this type and grade of oil worked exceptionally well in regard to total number of mixing passes required (4 passes)

to obtain a uniform mixture. Also, this mixture reacted very well during compaction and a smooth surfacing was obtained.

Bituminous Stabilizer 1000

Grade BS-1000 oil proved to be too highly viscous for this type of mixing operation and would "ball up" during the application pass and could not be uniformly distributed throughout the mixture regardless of the number of mixing passes that were made. Due to the mixing problem with the BS-1000 grade, a request for a slightly lower viscosity oil was made to the manufacturer who blended the remainder of the BS-1000 specified for the project to a BS-700 grade. The grade BS-700 worked very well in mixing, compaction, and final finish. The BS-1000 may have been suitable if the weather had been warmer.

SM-K and SS-K Cationic Emulsions.

The SM-K emulsion worked satisfactory but did not mix as easily or finish as smoothly as the BS-120 and BS-700 products. Also, the emulsion products have a tendency to "gum-up" the oil metering equipment and required frequent cleaning so that a uniform quantity of oil may be maintained during mixing.

The SS-K emulsion worked as good as the SM-K oil when the first truck load of material was being applied, but proved to be completely unsatisfactory when another truck load was delivered one day later. The bituminous material would "break" immediately when applied to the aggregate during the initial application pass and it was then impossible to conduct further mixing passes. Due to this problem, only the application pass with the mixer was attempted and the surfacing was smoothed for final finish by means of a motor grader following immediately behind the mixer. This type of operation produced a rough finished surfacing and uneven joints. The oil was sampled, tested and proved to meet specifications.

Numerous contacts were made with bituminous product manufacturers, but a definite answer concerning the problems with the one load of SS-K emulsion was not obtained from any source.

MC-800 Liquid Asphalt

MC-800 product worked satisfactory but did not mix as easily as the BS-120 and BS-700 grade oils. The oil, upon initial application, did have some tendency to "ball-up", but distributed throughout the mix effectively after several mixing passes were made. The MC-800 required two more mixing passes than the BS-120 product to obtain thorough mixing. Weather conditions varied to some extent from day to day during the mixing operations and this undoubtedly had some effect on the workability of the various bituminous products used.

Penetration Type Treatment.

BS-120 and BS-65 products were used in the surface penetration treatment test sections. The initial plans specified that BS-65 would be applied at a rate of 4.3 dm^3/m^2 (1.0 gal/yd^2) and BS-120 at 3.4 dm^3/m^2 (0.75 gal/yd^2). While oil spraying was being conducted on the designated section with the BS-120 product at a rate of 3.4 dm^3/m^2 (0.75 gal/yd^2), it was determined from visual observation that the remainder of the section should be treated with oil at a rate of 4.3 dm^3/m^2 (1.0 gal/yd^2). This revision was decided on because it appeared from previous experiences that the quantity of oil applied at the planned rate was not a sufficient amount to have adequate binding effect at the finished surface when treating cinder material.

The condition of the roadbed prior to applying the penetration treatment was satisfactory in all respects including base material compaction and moisture content.

oil product that worked exceptionally well in mixing and final finishing was BS-120, although the MC-800 and SM-K emulsion oils worked satisfactorily.

The type of Cross-Shaft In-Place Mixer used on this project was suitable as far as depth controls were concerned but it often was difficult to maintain a uniform flow of oil through the metering equipment which required continuous inspection and adjustment. Also, this machine is not as adaptable to a variety of conditions as some other types presently being used for in-place bituminous road mixing.

POST-CONSTRUCTION INSPECTIONS

The initial on-site inspection was conducted on 28 July 1969. The attached memo discusses this visual inspection and maintenance recommendations.

On 8 April 1970, another on-site condition inspection was made by Mr. Robert Hunt, of the EMIB on this roadway. At that time it was found that the road mix was in better condition than was anticipated. The surface of the mix is raveling to some extent in several areas but this problem can be expected due to traffic abrasion of the soft cinder material. A chip seal treatment should be applied as soon as possible. Some pot-holing has occurred in the surfacing and would require patching prior to the application of a surface treatment. The sections where BS oils were used are holding up very well although all sections will be satisfactory for a lengthy period of time if adequate maintenance repair is accomplished soon.

The roadway sections where a penetration-type treatment was applied have completely broken-up after being in-place two winters and used one full

PROJECT EXPENDITURES

1. The 1967 project costs amounted to approximately $58,000. Included in the project were setting up a work camp, opening and developing a cinder pit, preparing roadbed to receive base material, installation of a screening and loading plant, loading and hauling cinder material, blading and shaping base material and watering and compacting material. The watering Item proved to be extremely costly on this project due to length of haul and quantity required.

2. Due to the necessity of closing the project down because of climatic conditions in the fall of 1967 and the need to completely recondition the roadway base in 1968 prior to completion of the project, it was necessary to spend an additional $16,000. The 1968 expenditures involved re-establishment of work camp, reshaping in-place roadbed material, hauling additional cinders, blading and compacting base material. This 1968 expenditure has to be included in the total project cost but this cost would not have occurred if the initial project planning schedule could have been maintained.

3. The total quantity of bituminous products incorporated into the project was 576.16 tons at a cost of $26,331.76. The total oil costs included excess spread time and truck standby time. These standby costs were due mainly to problems with the mixer and the difficulties that developed in handling some of the emulsion products which caused delays in unloading and releasing the oil distributor trucks.

GRADE OF OIL	PROJECT QUANTITY (TONS)	UNIT PRICE (TONS)	TOTAL COST
BS-65 (In-Place Mixing)	45.64	$ 45.80	$ 2090.31
BS-120 (In-Place Mixing)	152.91	$ 43.70	$ 6682.17

Continued -

GRADE OF OIL	PROJECT QUANTITY (TONS)	UNIT PRICE (TONS)	TOTAL COST
BS-120 (Truck Spread)	26.14	$ 44.80	$ 1171.07
BS-1000 (In-Place Mixing)	105.69	$ 42.70	$ 4512.98
MC-800 (In-Place Mixing)	51.09	$ 35.20	$ 1798.37
SM-K (In-Place Mixing)	98.31	$ 44.10	$ 4335.47
SS-K (In-Place Mixing)	98.38	$ 44.10	$ 4250.35

PROJECT CONSTRUCTION

EMIB personnel provided project materials testing control and technical assistance during construction. The EMIB portable field testing laboratory was stationed near the center of the project where it was utilized continuously conducting grading, extraction and stability testing prior to and during construction.

The test data obtained from materials samples tested during construction was considered as representative only at the individual area sampled and could be utilized only for the immediate project controls. A completely valid post-construction evaluation of the test project in regard to the planned sections and reaction of individual bituminous products should not be attempted because of the amount of base materials segregation and contamination that had occurred in the individual areas of designated sections prior to being treated. This contamination was caused by reasons discussed previously in this report.

The in-place mixing operation proceeded slower than was anticipated because of cool climatic conditions, minor equipment break downs and the problems that developed in handling the SS-K emulsion and BS-1000 oil products. The

oil product that worked exceptionally well in mixing and final finishing was BS-120, although the MC-800 and SM-K emulsion oils worked satisfactorily.

The type of Cross-Shaft In-Place Mixer used on this project was suitable as far as depth controls were concerned but it often was difficult to maintain a uniform flow of oil through the metering equipment which required continuous inspection and adjustment. Also, this machine is not as adaptable to a variety of conditions as some other types presently being used for in-place bituminous road mixing.

POST-CONSTRUCTION INSPECTIONS

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The roadway sections where a penetration-type treatment was applied have completely broken-up after being in-place two winters and used one full

season by recreation traffic.

Apparently the quantity of oil applied during the treatment was not sufficient to adequately bind and stabilize the cinder materials. Also, the contamination problem of base material could have been a contributing factor.

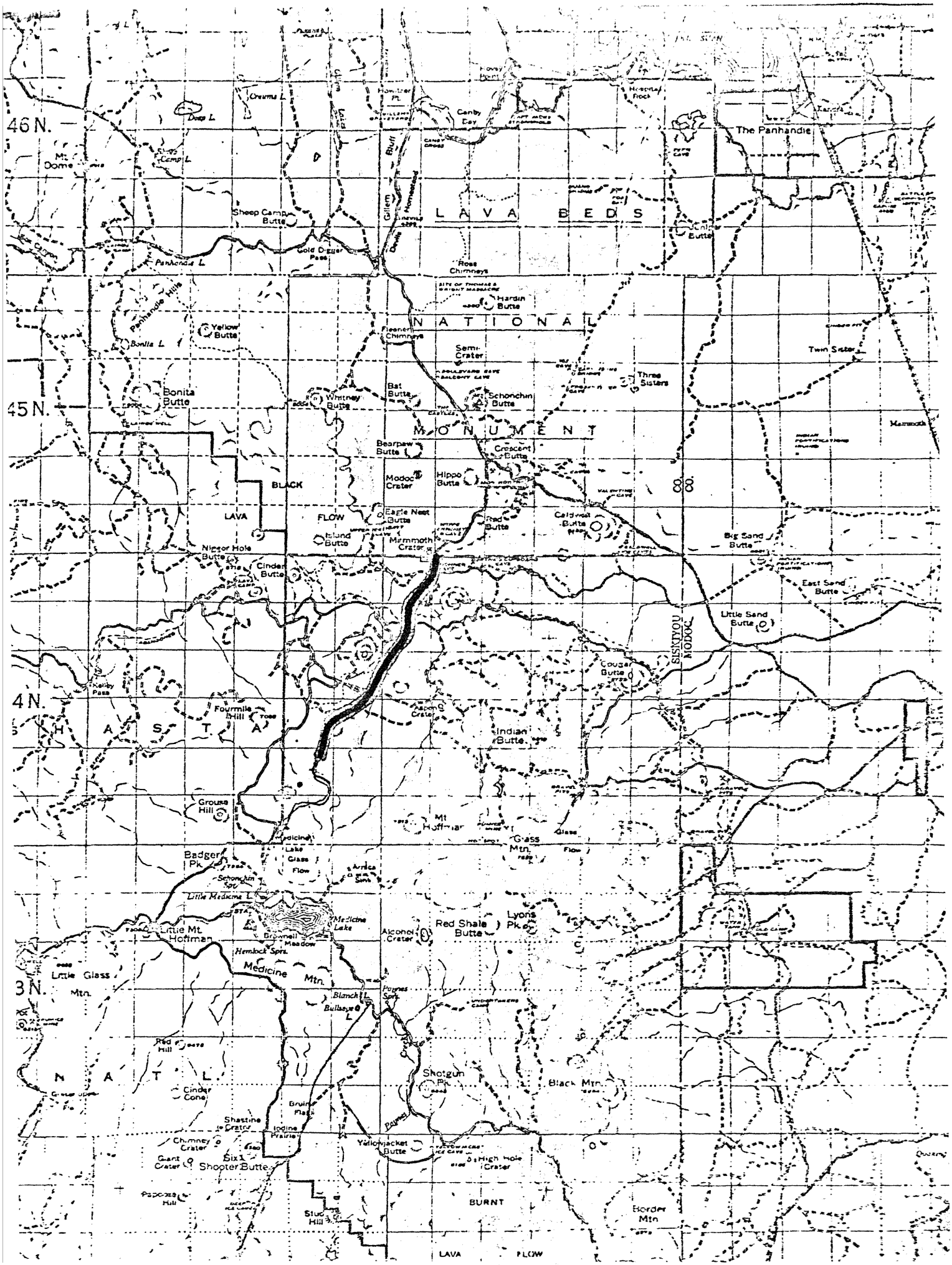
GENERAL COMMENTS

1. One of the key factors in regard to the success of a roadway test project is the planning and programming of the required construction finances. The funds for this type of project must be available at a scheduled time so adequate planning may be accomplished concerning project work schedules, equipment and materials procurement, etc. The Medicine Lake project financing was obtained so late in the construction season in 1967 that climatic conditions and the difficulty in obtaining suitable equipment could adversely effect the success of the project as a test section. Also, the $16,000 expenditure in 1968 would have been unnecessary if funds were available at an earlier date in 1967. Adequate funds should also be programmed so some float time is available during construction. The programmed work schedule should not be so firmly set and controlled directly by financing that unscheduled revisions cannot be made in regard to construction procedures, quantity adjustments, etc.

2. All of the bituminous products used on the project proved to be compatible with cinder type materials in regard to the finished product structural qualities even though varying degrees of mixing difficulties were encountered when the emulsions products were being used.

3. At the present time several road mixing projects constructed during the past two years by various mixing methods are being evaluated. The mixing equipment used on these projects proved in various ways to be superior to the type of mixer used on the Modoc test section. The important items found on some of the other types of machines are the more accurately controlled oil supply systems, thorough mixing requiring fewer mixing passes and they also leave a smooth finished mat that does not require further preparation prior to being compacted.

4. When evaluating the present and future maintenance costs on this test section we should take into consideration the contamination and materials segregation that had occurred in the base materials prior to being treated.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LAVA BEDS
NATIONAL
MONUMENT
The Panhandle
Mt. Dome
Sheep Camp Butte
Gold Digger Pass
Ross Chimneys
Hardin Butte
Yellow Butte
Bonita Butte
Whitney Butte
Bat Butte
Schonchin Butte
Three Sisters
Twin Sister
Bearpaw Butte
Crescent Butte
Modoc Crater
Hippo Butte
BLACK
LAVA
FLOW
Eagle Nest Butte
Island Butte
Mammoth Crater
Red Butte
Caldwell Butte
Big Sand Butte
East Sand Butte
Little Sand Butte
Nipgor Hole Butte
Cinder Butte
SISKIYOU
Cougar Butte
Indian Butte
Fourmile Hill
HASTA
Grouse Hill
Mt Hoffman
Glass Mtn.
Badger Pk.
Little Medicine L.
Medicine Lake
Little Mt Hoffman
Alconot Crater
Red Shale Butte
Lyons Pk.
Hemlock Spr.
Medicine Mtn.
Little Glass Mtn.
Blanch L.
Bullseye L.
Red Hill
NATL
Cinder Cone
Shotgun Pk.
Black Mtn.
Shastina Crater
Chimney Crater
Giant Crater
Six Shooter Butte
Yellowjacket Butte
High Hole Crater
Papoose Hill
Stuck Hill
BURNT
Border Mtn.
LAVA FLOW

ENGINEERING MATERIALS INVESTIGATIONS BRANCH
701 N. Santa Anita Avenue
Arcadia, California 91006

Forest Supervisor, Modoc National Forest 7700
Attention: Russ Schwulst, Forest Engineer

Leonard J. Stern, Materials Engineer 28 July 1969

Transportation System - Medicine Lake Road
Surfacing Inspection and
Project Evaluation

Reference is made to the inspection and evaluation of the Medicine Lake roadway surfacing that was conducted on 16 July 1969. The inspection group consisted of Leonard J. Stern, Materials Engineer and Robert Hunt, Engineering Technician, Engineering Materials Investigations Branch and Russ Schwulst, Forest Engineer, Dick Williams, Administrative Officer, and Clarence McCully, C&M Foreman, Modoc National Forest.

This project, 7.68 km (4.77miles) in length, was constructed during September 1968 and consisted of the placement and bituminous treatment of cinder material for roadway surfacing.

The project was proposed, designed and constructed as a test section using numerous types and grades of bituminous products applied at varied designed and controlled quantities. The cinder material was treated by in-place road mixing and penetration methods. The mixing method consisted of treating the cinders by mixing various types and grades of bituminous binder at various application rates and depths. The penetration-type treatment consisted of applying two (2) grades of asphaltic binder to the cinder material in varied rates of application.

This test project was proposed and designed for obtaining data to evaluate the effectiveness, design limitations and economic factors in regard to treating cinder-type material with numerous bituminous products using varied construction procedures. As was anticipated, some surfacing failure has occurred since construction, but the failed areas proved to be only in sections where penetration-type treatment was applied. Surfacing damage in some sections treated by penetration methods is limited to potholing and surface raveling on curves and in other sections the surfacing has completely failed.

It was found, during our on-site inspection and review of the original laboratory test data, that in most of the areas the test results and field results showed good correlation in regard to depth of penetration.

It is our opinion that complete failure found in some sections can be mainly attributed to materials contamination and depth of the base material that was treated. We realize that due to being placed several months prior to being treated, base material in some areas was contaminated to some extent by subbase soils. In areas where the cinder base material proved to be in excess

of 51 mm (2 inches), a consolidation or lateral movement may have occurred causing breakup of surfacing. Because of the contamination mentioned previously, we are unable to fully evaluate the actual cause of the breakup in this section.

In sections where the cinder material was treated by in-place road mixing methods, the condition of the mix itself was found to be generally very good regardless of the bituminous product used during treatment. However, due to the softness of the cinder-type material, the surfacing is starting to show signs of minor raveling being caused by abrasion of these materials under traffic conditions.

In some areas on this project, the rising surface of the roadway does not meet expected standards. All personnel closely concerned with this project realize the roughness of the surfacing is directly related to equipment problems and our inability to adequately mix and place one (1) type of emulsion during construction. Although some of the emulsion material used proved difficult to handle during construction, the emulsion mix appears to be very stable and durable at the present time. The sections in which BS-120 oil was used for in-place mixing proved to be the most satisfactory in all respects during construction, and at present appears to be an excellent product for treatment of cinder material.

In sections where MC products were used on the project, the roadway surfacing is rougher to some extent than in the Bituminous Stabilizer sections. Although the mix itself appears satisfactory, there appears to be more surface raveling occurring at present than in the sections using BS products.

Prior to winter closing this area, another inspection will be made of this project and a complete bituminous product, roadway condition survey and construction procedure evaluation will be prepared as concerns this projeet.

In order to have a suitable surfaced roadway for public travel and to prevent the loss of the base material now in place in the penetration sections where complete failure has occurred, and also to protect our initial investient in other sections, the following repair and maintenance work is recommended on this roadway.

The penetration treatment sections where damage is limited to potholing and surface raveling may be repaired by patching potholes with pre-mix material and applying a penetration oil to the severely raveled areas. A chip or sand seal should then be applied over the total section. To prevent "stripping" during chipping operations, it will probably be necessary to provide a three (3) day curing period for the penetration treated areas prior to start of chip sealing.

The surfacing on penetration sections where complete failure has occurred should be reconstructed by means of motor grader mixing and laying. MC-250 liquid asphalt will be the most economical and easiest to use in this type of operation and should be applied at 14% by oven dry weight of aggregate. One roller (pneumatic) is all that would be necessary for compaction of this mix and will also be the type roller that is best suited for rolling the chip or sand seal that should also be applied on this section after reconstruction is completed.

All sections and areas of the mixed in-place sections should also be treated with a chip or sand seal to protect against further abrasion and raveling damage to the immediate surface of the roadway being caused by traffic due to the softness of the cinder-type material.

Aggregate to be used for sealing all sections of the project can either be processed chips or a coarse graded sand, whichever proves to be most economical, although chips are preferable if costs are comparable.

Processed chips should be applied at approximately 13.5 kg/m^2 (25 lb/sy) using RS-3K emulsion applied at a rate of 1.13 dm^3/m^2 (0.25 g/sy). If sand is used for sealing, the application rate will be approximately 13.6 kg/m^2 (25 lb/sy) and the oil at 1.36 dm^3/m^2 (0.3 g/sy). Final application rates of oil or aggregate will be dependent on actual aggregate size of material selected for the sealing operations.

If pre-mix material needed for patching purposes proves to be difficult to obtain, this mix can be processed on the site while mixing is being conducted on the penetration area that is to be reconstructed. If it is felt that a levelling course is needed in some areas to smooth the riding surface, the material can also be processed on-site for this purpose while processing patching material. If leveling courses are applied in some areas, an emulsion tack coat should be applied prior to placement of the mix by means of a motor grader.

Please contact us if further assistance is needed in regard to repair or maintenance items discussed in this memo.

cc: Regional Engineer

RWH:onf

MEDICINE LAKE ROAD

PLANNED SECTION

9/10 - 9/18/63

SHEET #1

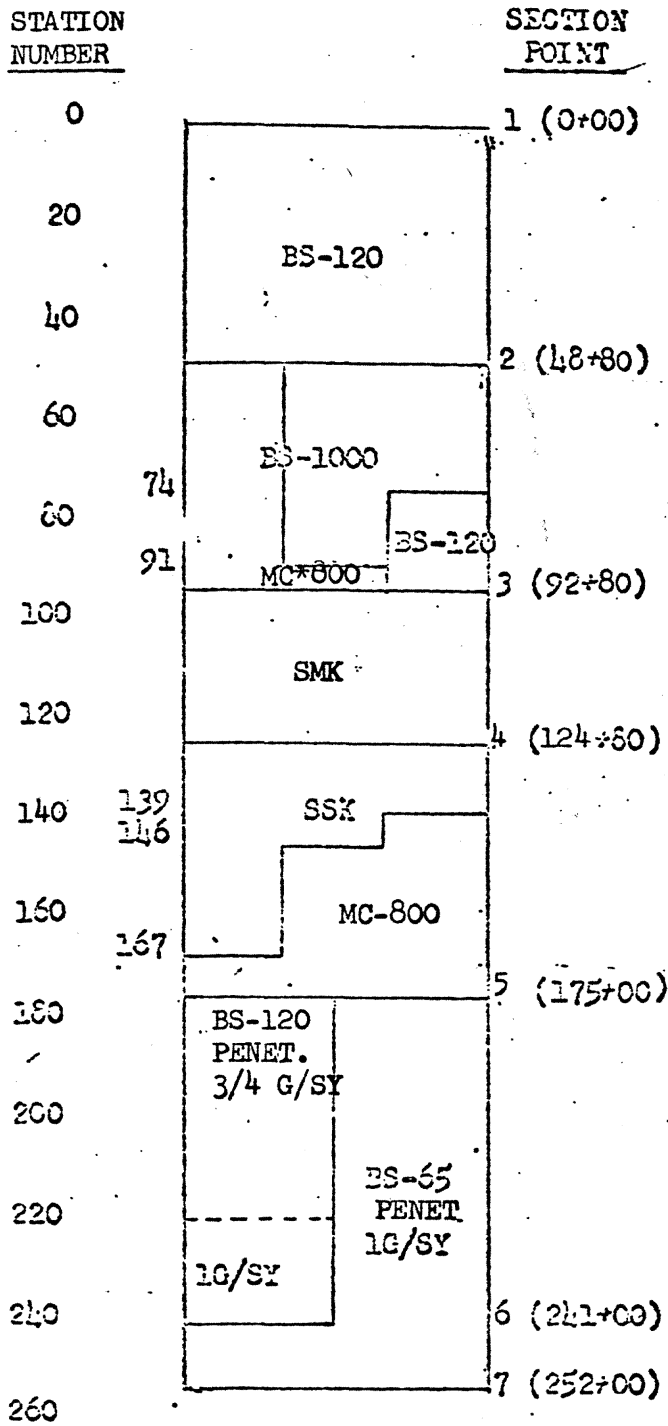
STATION NUMBER	GRADE LIQ. ASPH	TONS LIQ.ASPH	PERCENT LIQ.ASPH.	MIX DEPTH INCHES
0				
	BS-120		16	3
20		132	16	2
			20	2
40			20	3
	BS-1000		16	2
60		132	20	2
			16	3
80			20	3
	SMK		18	3
100		96	18	2
	S&K		18	3
120		96	18	2
140				
	MC-800	50	7	2
160				
180			1 GAL/SY	
	BS-65 PENET			
200		50		
220			3/4 GAL/SY	
240				
	BS-120 PENET.	50	1 GAL/SY	
260			3/4 GAL/SY	
280				

MEDICINE LAKE ROAD

AS CONSTRUCTED

9/10 - 9/18/68

SHEET #2

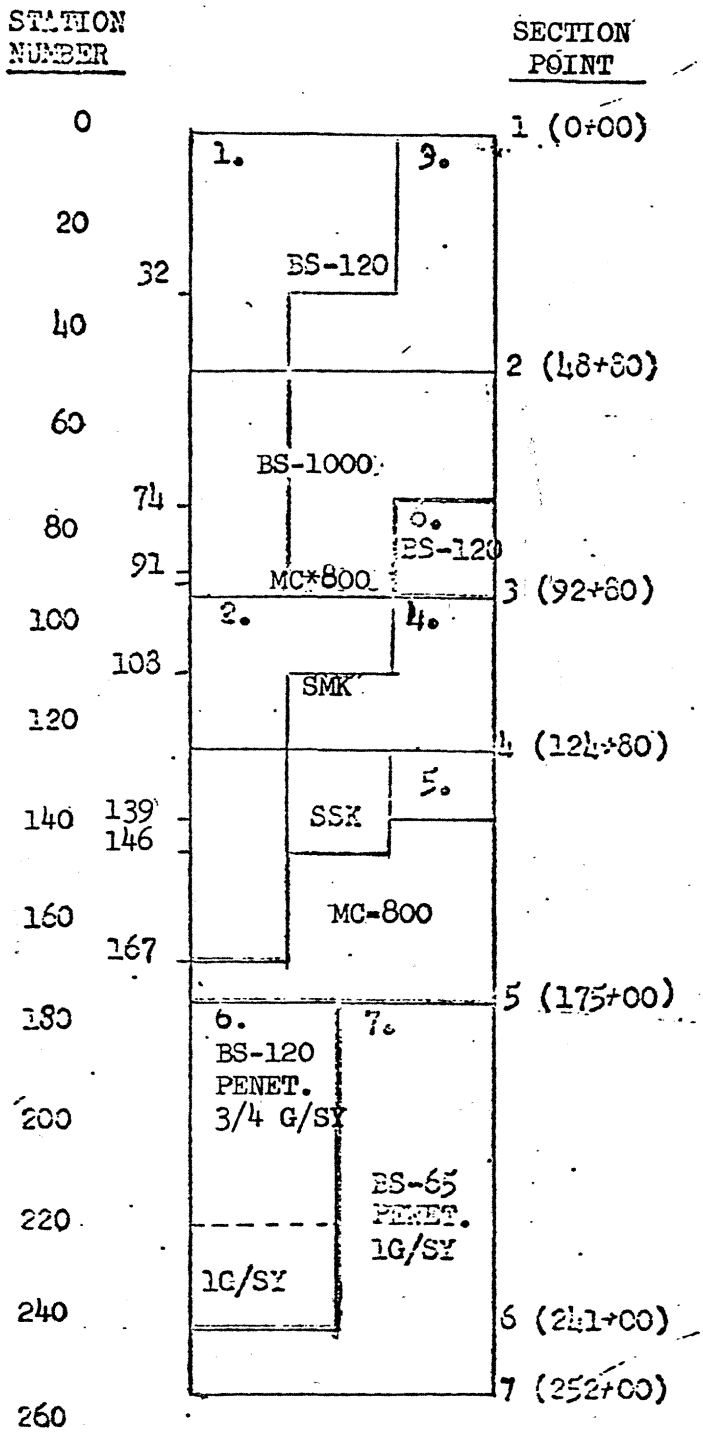


MEDICINE LAKE ROAD

AS CONSTRUCTED

9/10 - 9/18/68

SHEET #3



DAILY PRODUCTION

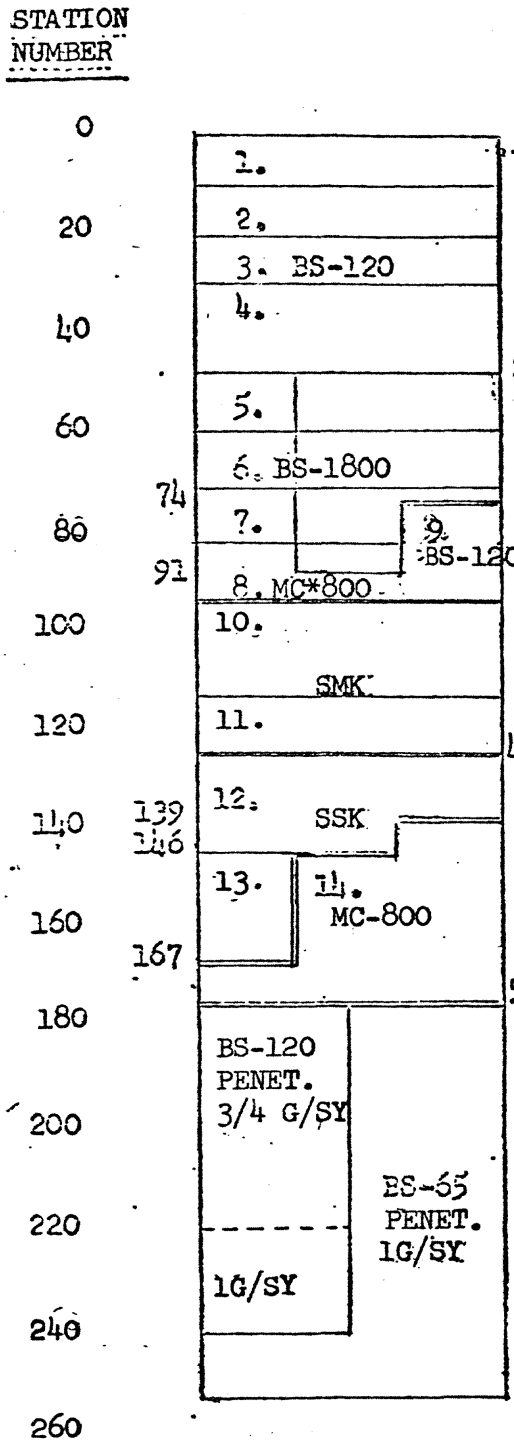
1. Tues 9/10/68
2. Wed 9/11
3. Thur 9/12
4. Fri 9/13
5. Mon 9/16
6. Tues 9/17
7. Wed 9/18

MEDECINE LAKE ROAD

AS CONSTRUCTED

9/10 - 9/18/68

SHEET #4



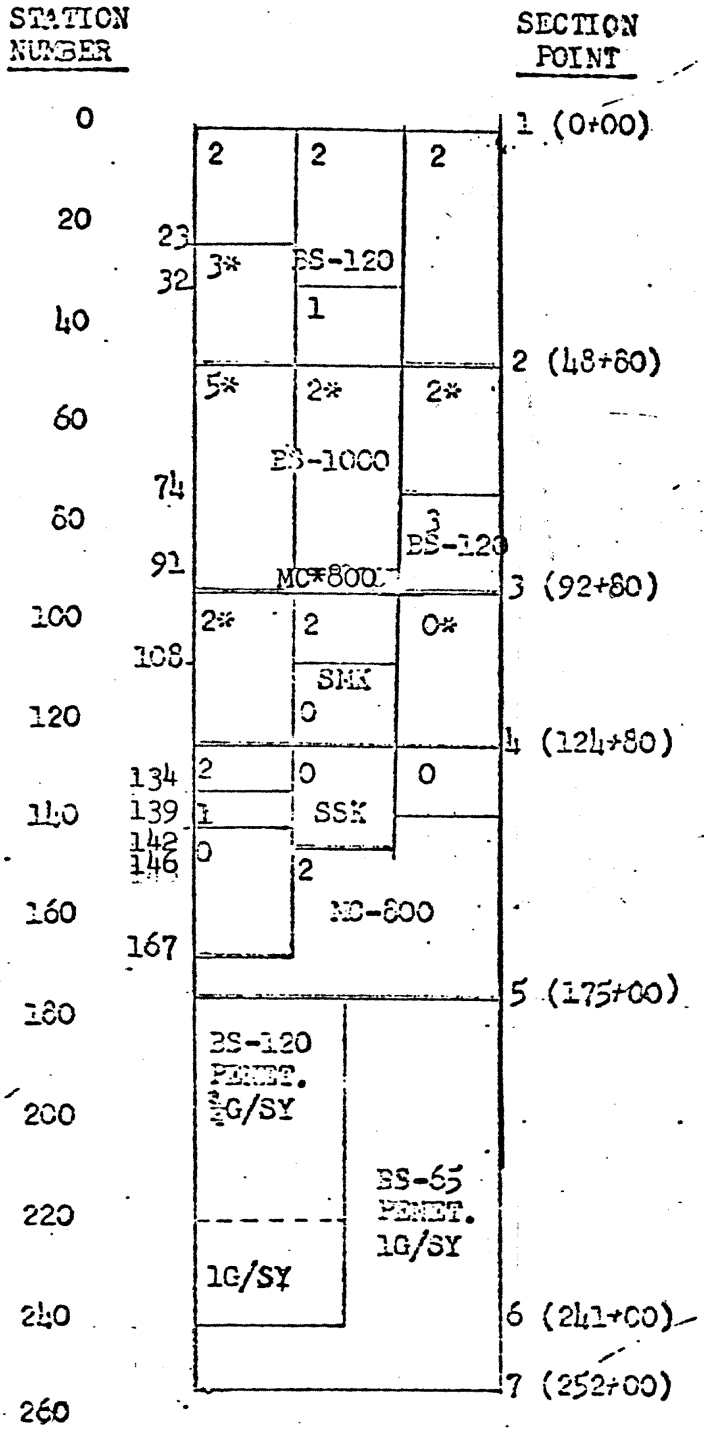
	STATION, % LIQ. ASPH., & MIX DEPTHS		
1.	0+00 - 10+00	16%	3"
2.	10+00 - 20+00	16%	2"
3.	20+00 - 30+00	20%	2"
4.	30+00 - 48+80	20%	3"
5.	48+80 - 59+80	16%	2"
6.	59+80 - 70+80	20%	2"
7.	70+80 - 81+80	16%	3"
8.	81+80 - 92+80	20%	3"
9.	74+80 - 92+80	16%	2"
10.	92+80 - 113+40	18%	3"
11.	113+40 - 124+80	18%	2"
12.	113+40 - 146+00	18%	3"
13.	146+00 - 167+00	18%	2"
14.	139+00 - 175+00	15%	2"

MEDICINE LAKE ROAD

AS CONSTRUCTED

9/10 - 9/18/63

SHEET #5



MIXING PASSES

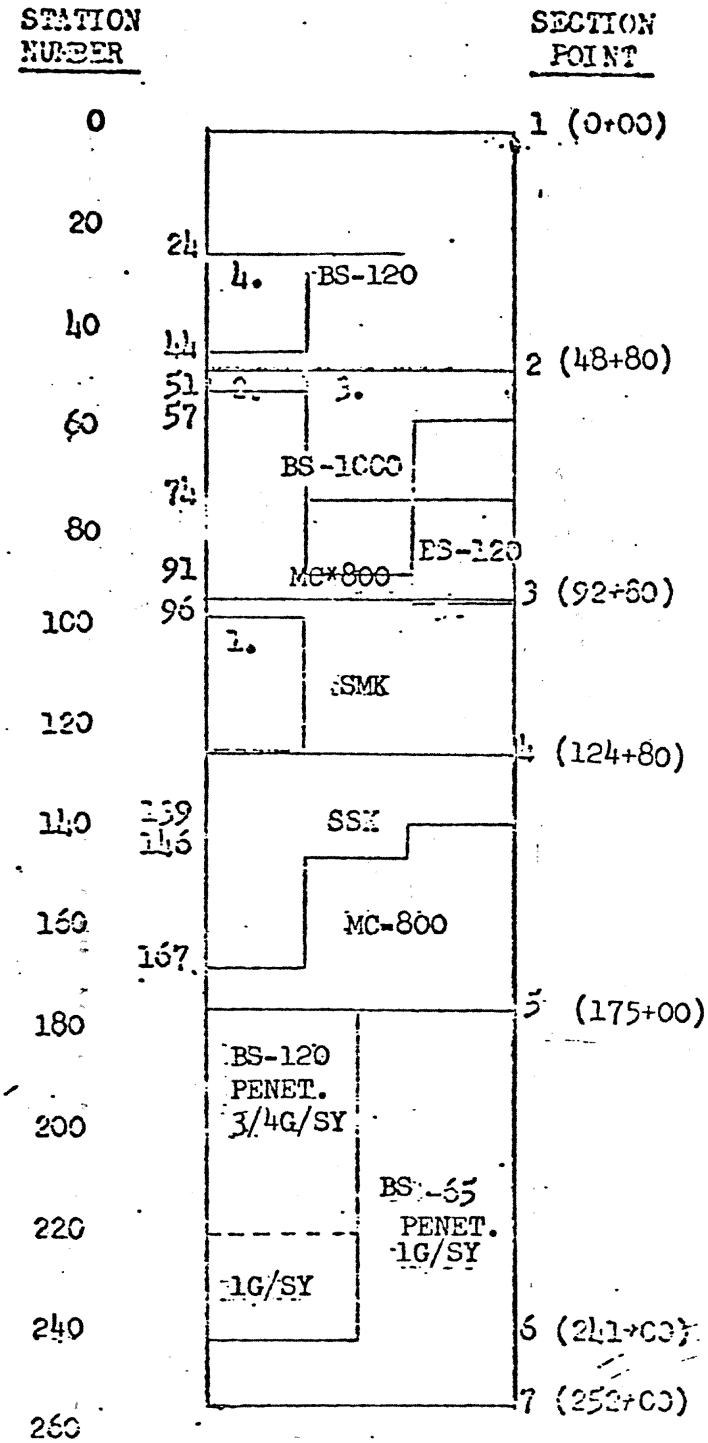
EACH NUMBER INCLUDES THE NUMBER OF TIMES MIXED AFTER INITIAL MIXING WITH LIQUID ASPHALT.

*ADDITIONAL MIXING PASSES WERE MADE AS INDICATED ON SHEET #6

AS CONSTRUCTED

9/10 - 9/18/68

SHEET #6



ADDITIONAL MIXING

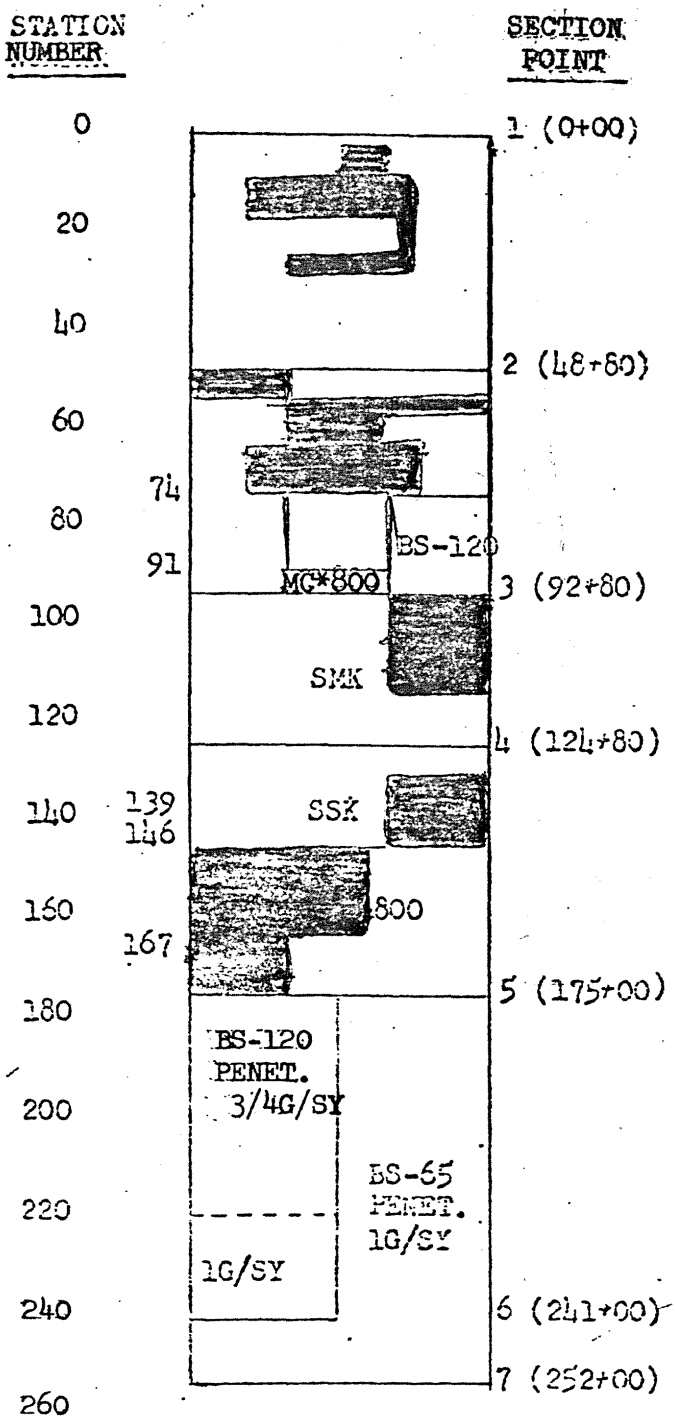
1. 9/11 - STA. 96+00 - 124+80 RT.: REMIXED WITH SMK PLUS 1 DRY MIXED PASS.
2. 9/12 - STA. 48+80 - 51+50 RT.: REMIXED WITH BS-120 PLUS 1 PASS DRY MIXED.
3. 9/16 - STA. 48+80 - 74+00 MID., 48+80 - 57+00 LT.,& 48+80 - 51+50 RT.: 2 PASSES DRY MIXED.
4. 9/17 - STA. 24+50 - 44+50 RT.: REMIXED WITH BS-120 PLUS 2 DRY MIXED PASSES.
5. 9/17 - STA. 92+80 - 93+55 LT.: REMIXED WITH BS-120 PLUS 3 DRY MIXED PASSES.

MEDICINE LAKE ROAD

AS CONSTRUCTED

9/10 - 9/13/68

SHEET #7



9/18/68 - BS-65 FOG SEAL @ 0.07 GAL/SY

1+00 - 9+50	4' WIDE	LT. SIDE
9+50 - 19+50	12	MID.
19+50 - 24+50	2	LT.
24+50 - 30+00	8	MID.
48+50 - 52+50	6	RT.
52+50 - 57+00	12	LT.
57+00 - 62+50	6	MID.
62+50 - 73+50	12	MID.
92+80 - 114+00	6	LT.
129+00 - 146+00	6	LT.
146+00 - 165+00	12	RT.
165+00 - 175+00	6	RT.

TOTAL GALLONS USED : 750

Next we have a logging company representative -- a partner in Bly Logging Company, Mr. Kennedy. Bob was a logging camp foreman from '41 to '44. He completed his education in '44 and '45 with a Degree in Logging Engineering from the University of Washington. From 1945 to 1957, he worked as a woods engineer and logging superintendent for Kinzua Corporation and Weyerhaeuser Co. In 1957, he became a partner in Bly Logging Company.

In the 13 years he has been with Bly Logging he has had extensive experience in building roads through, and with volcanic materials; and I imagine he has driven enough miles over these roads that his lungs can't function if they aren't coated with pumy dust. Bob, it's all yours:

COMMENTS OF ROBERT B. KENNEDY

of

Bly Logging Company

presented at the

WORKSHOP ON LOW CLASS ROAD CONSTRUCTION
USING VOLCANIC CINDERS AND PUMICE

at

Klamath Falls, Oregon

October 5, 1970

Comments of Robert B. Kennedy presented to Workshop on "Low Class Road Construction Using Volcanic Cinders and Pumice."

It has been said that human beings are like Chameleons. To survive they may not change colors but they do change characteristics to fit the environment they are in. As an example, today's youth, when with their peers, must be vocally anti establishment, against the use of our natural resources, in love with all mankind, against any form of discrimination, etc. Their grooming and clothes have a distinct look to fit the environment. Now, when these same youth go into the business world, they change, appearance-wise they adjust to what their fellow workers look like, be it blue collar or white collar. They conform to their surroundings and that is what we all do.

As a forester, logger, engineer, I find that I change my language, my grammar, and even my thoughts, depending on what group I am with. This may be hypocritical but I think it applies to nearly everyone. The transition is probably most pronounced when the comparison is made between my speech and actions as a logger and my speech and actions in church or at P.T.A. meeting.

The point I am making is that after attending many, many meetings of many and varied organizations I have found the people in attendance too often say what they think the group wants to hear and thereby blend into the environment as an accepted member, believing what everyone believes.

Spiro Agnew probably says what he thinks his immediate audience wants to hear but he very definitely is speaking against the fadisms

of the day and, if people will analyze what he has to say in an objective and factual light, his words make some sense and surely provide some balance and criticism to an otherwise popular dogma that by some standards you must believe in or be an outcast.

Now I am not a Spiro Agnew but I expect my remarks to possibly be a little different than the general trend of this meeting.

The subject matter of the meeting, as I gather from my letter on the subject, is divided into two categories. Number one is pumice roads and number two cinder roads.

As far as pumice roads are concerned, I feel that the Forest Service has found a solution to which there is absolutely no problem. There is no better road to work on than a pumice road such as those that existed on the Klamath Indian Reservation when it was terminated.

This is a road that does not have, or need, culverts except in active streams. Does not have, or need ditches.

The grade has not been cut deep enough to put roadbed beneath the pumice cover and into the clay and boulders. The back slope is vertical. In short, at its best it is a wide flat-bottom ditch.

Now when engineers, not used to working on pumice, come into the ares they are shocked and set about changing all this. They design roads with back slopes of 2 to 1 or flatter, thereby taking out areas of land that could be productive but not eliminating slough into the ditches they have designed into the road. These ditches are soon filled up or, if they do pick up water, they soon wash deeper. They design cuts that go through the pumice into the clay and boulders

Which reminds me of advice that my barber gave his teen-age son. He said, "Son, you will not live long enough to make all the mistakes that can be made. You should profit by the mistakes of others as well as what they have done right."

The other topic we are to consider is cindered roads. There is no question that much of the ground area on the Fremont and Winema Forests is composed of clay and boulders. Here, the usual engineering techniques apply. The only word of caution or comment is that I would hope that we have good sound reasons for a highly engineered road with surfacing and the extreme right-of-way width required, with the attendant costs. If the road of high standards is required, then, of course, cinders are available and inexpensive and should be used.

I started building truck roads and railroad grades on Forest Service lands as an equipment operator for my dad in 1938. This was on the Liberty Ranger District in the Snoqualmie National Forest in Washington on a land exchange between the Cascade Lumber Company in Yakima and the Forest Service. At that time the staff at the Ranger Station consisted primarily of a Ranger and his assistant. The assistant marked the timber and cruised it. He did everything else that was necessary on the timber sale and I felt the taxpayer really got his moneys worth. At that time we put our roads where we wanted them and to the standards we wanted.

My next experience with road building was as an engineer for Kinzua Corporation in charge of road building, road locating and inspection of a road building contractor that was working for them. There was a strike

in the woods industry that year and after its termination I went to work for Weyerhaeuser at their Snoqualmie Falls branch. There I was the engineer in charge of road location and construction. This was on private and State owned land. Construction methods were power shovels working on mats and a few cats when weather and ground conditions permitted. Ballast was glacial deposits loaded by power shovel and back filled with dump trucks.

Then back to Eastern Oreg. as Logging Superintendent and Logging Manager for Kinzua Corporation. This company built excellent roads on private land and eventually into Forest Service lands. Our main line to the reload was 17 miles of two-way oil mat road. This went to the railroad reload and was a nice road but not the answer to an off highway haul in Eastern Oregon. We made it work but it was a very costly road and was kept intact only because the man who said it was the road to build did not want to be proved wrong. When we did away with the reload and extended the truck road to the mill this road was never oiled, and as the road was extended into the timber it was never oiled. We did experiment with everything in the way of clay binder and dust abatement. Wetter water chemical, Reynolds soil packer, water mix dust abaters, oil dust coats and anything else that showed promise. All oil dust coats either set up in spots with a mixture of severe chuck holes or just disappeared under traffic. When I left Kinzua and came to Klamath Falls I had spent some 19 years working with all kinds of road building and design. This was in 1957 and I was, and still am, convinced that the cheapest material available, water, is the best and

overall cheapest dust abatement possible. The only exception would be a road with a terrific total volume and a terrific daily volume to come over it. This alone would justify a deep solid ballast base necessary for an oil mat.

About 2 years ago we conducted an experiment with a substance known as Paczyme that was supposed to make soil pack harder and thus require less water, but results again were disappointing.

Over the years I have watched many experiments and have come to the conclusion that each generation has to come up with what they think are new ideas but, actually, if they will check back, these ideas have probably been used before. There is very little new under the sun and even fewer new ideas.

As far as cinder roads are concerned, I don't feel they should cover pumice. They should have clay mixed with them and be packed and sealed over before the fall rains. Many times we have hauled on cindered roads and our trucks have had to be pushed through or else a road up the borrow pit used, or a road around the cindered road built. This is simply because the cinders are porous, allowing the liquid through but then forming an insulating layer that holds the moisture in the subgrade throughout the summer.

I do feel that because we are oriented to cinders in this area we often bypass many good rock formations that would make excellent ballast material. When this material is found it should be possible to use it without first getting approval of Congress.

So I would conclude with these thoughts:

Don't destroy a good serviceable pumice road.

When cinders are used, mix with water and clay, roll and seal and then plan on water for dust abatement and less maintenance.

Don't parrot your associates' views unless you have given serious thought to them and really believe them. Be sure the idea is new, had not been tried and, above all, is practical. When you do apply the idea, be sure it is given an honest evaluation and all facts are considered with no attempt to slant it to make it come out with the results you want.

Last, but not least, is Klamath County Engineer, Dave Hoerning. Klamath County uses cinders extensively as a base course and aggregate for bituminous surface. I don't think they like volcanic materials though, since they are continually trying to cover them up with asphalt.

Dave has been County Engineer for Klamath County for 2 years. Prior to that he was in private practice for 4 years, and prior to that was with the California Division of Highways for 9 years. He is a Registered Civil Engineer in three States. With that, Dave, I'll turn it over to you for a run-down of how Klamath County handles volcanic material:

THE USE OF VOLCANIC CINDERS IN COUNTY ROAD CONSTRUCTION AND MAINTENANCE

By

Dave Hoerning
Director of Public Works
Klamath County, Oregon

Presented at the

Workshop on Low Class Road Construction Using Volcanic Cinders & Pumice

at

Klamath Falls, Oregon

October 5, 1970

In the use of cinders and pumice by Klamath County, I will mention that any classification is based on our own experience and observations. Any reference made to a certain type of cinders would not necessarily be the technical description given by a Geologist.

We classify cinders, primarily as being either black, gray or red and each classification contains a multitude of grades.

Black cinders, insofar as the many cinder pits we have worked, have proven to be the hardest. In fact, some will pass the Oregon Degradation Test.

Gray cinders are next on the scale for hardness and degradation.

The red cinder ranges from good to poor for hardness. We have found them to be generally lighter or fluffier than the black cinder. This may be an indication that they have undergone considerably more heat during the upheaval period.

The Road Department has used a great deal of cinders in many ways. We have been very successful in using them for base course, leveling course and asphaltic mixed pavement.

The base course material is generally crushed to an inch and one-half minus (1-1/2" - 0) specification. Clean cinders are useless, therefore a binder should be added at a rate of twenty (20) to thirty (30) percent depending on the binder. Most cinder pits have a natural binder within the overburden and through selective feeding to the crusher, can be mixed with the cinders to obtain the desired product. We have utilized, at times, pit run material as a base course. However, a higher quality base job is

obtained by using a uniform mixture of 1 1/2" minus. In either event, the use of a grid roller for compaction is essential, plus adequate moisture.

The leveling course is crushed to a 3/4" minus gradation and it should be blended with a binder same as the base course. One important factor, is that if a 3/4" minus leveling course is applied, it should be placed immediately upon the base course to insure and allow complete bonding of the two materials. We have found in some cases, that if there is a considerable lapse of time before the leveling course is applied, the base course becomes well stabilized (or glazed) and it is impossible to bond the two materials together. This, naturally causes a slippage plane between the two layers and can only be corrected by scarifying the base, relaying and immediately applying the leveling course.

Consideration can be given to eliminating the leveling course if the base course is of proper quality, sieve count, and paving is to follow in the near future, or at least a prime. (MC-800 and cover)

Our asphaltic concrete is a pugmill mix of 3/4" minus material and asphalt. The production of this material is the reverse of base and leveling. We generally scalp with a 3/4" screen, then reduce the balance down to 3/4" minus. (no dirt)

We have used all types of cinders, several types of asphalt, with many end results, ranging from very good to fair. We generally know, by or before the first load is put down what troubles to expect. The formula or percent of asphalt in each particular type cinder varies considerably. In the use of cutter type of liquid asphalt, we have run from 8% to 11%

product using an MC-800 or RC-800. This type of asphalt has residual of approximately 75%, which means your actual asphalt content is about 20% less than total product.

There has been several projects paved with emulsion type asphalts. Usually we experimented to obtain the desired amount of asphalt in the mix. We have found with SSK an 8% product plus 3% additional water for a total of 11% fluid has given us a satisfactory surface.

The use of SMK with 8% product and no additional water produces a successful mat. However, it is usually very tender, and slow-setting compared to CMK, this creates problems due to the fact we cannot close the road to traffic.

The best end result has been CMK with 12% product and no additional water. It is desirable because it is a quick setting asphalt and produces a tough durable pavement. Using the black cinders, we were able to produce an open-graded material which is a necessity when you use CMK. We found the mix could be rolled immediately following lay-down, choked (sanded), finished rolled and open to traffic without detrimental effect to the finish.

The main problem we have with CMK is at the paver, due to the quick setting of the mix. If the paver could operate continuously, not have to wait for a truck, this would curtail most of the problems; however, this is not always possible. Even if this were possible, there is still the problem of material hanging up between the moldboard and augers. This material becomes stiff or partially set and when the paver resumes forward

travel, after having stopped for whatever reason, the material will tend to tear-up the mat, by part of this "dead material" dropping or working down. This, of course, makes it difficult to lay a smooth even mat. Even with the problems mentioned, our crews were able to produce what I would call a good riding surface.

I am certain that if a mechanical device could be installed on the paver, assuming one could be designed, to force this dead material on through and not allow it up build up in the first place, then we could have an asphalt that is the next best thing to hot mix, if not almost as good for the type of roads we are paving. However, it should be pointed out that the previous mentioned problems existed when we were using crushed rock, and is not just a problem relating to cinders and CMK.

Also, we have experienced a very abrasive action on all metal coming in contact with the CMK mix; the slat conveyor at the pug mill, slat conveyor on the paver, the screed, but feel that we can live with this.

SUMMARY OF QUESTION AND ANSWER SESSION
TO
PANEL MEMBERS
by Tom M. Kerns

Since the Question and Answer session was informal and several of the panel members would comment on one question, no attempt has been made to tie the answers to any single panel member.

1. Q. How do you maintain a cindered road with oversized material in the cinders?

   A. No real solution after the material has been placed on the road except the possibility of a "Teco" or "Tomahawk". The best solution is to remove the oversized at the pit.

2. Q. Can clinkers be crushed due to hardness?

   A. Klamath County tries to avoid clinkers, and not crush them. On the East-West pit on the Winema National Forest, a large amount of clinkers were crushed.

3. Q. Would the panel comment on proper pit development?

   A. A plan needs to be developed at the time a pit is opened up to provide for ultimately putting the pit area back into production. This plan should provide for stockpile areas for overburden material where the material is retrievable, for disposition of oversized or unusable material, and for final pit shape and slopes. It should also provide that the pit remain in an operable condition at the termination of each user's operation.

It doesn't always work this way because development plans do break down, leaving a hardship on the next operator.

In order to have a meaningful pit development plan, sufficient subsurface exploration needs to be done so the people preparing the development plan know exactly what the material is and where it is.

On the Fremont Forest, it is felt that screening causes problems in pit development because of the large pile of reject material that accumulates. It is felt screening in a pit should be avoided.

Oversize material along the road is also objectionable due to aesthetics and wasteful haul costs.

4. Q. What were the costs on the Studhill Road on the Shasta Trinity National Forest using a penetration treatment and chip seal, as reported by Leonard Sterns?

   A. The costs aren't available at this time. The cost for oil BS-120 was approximately $40 to $42 per ton in place.

5. Q. Is the Studhill Road bladeable?

   A. No. BS is not bladeable.

   Region 5 is working on an emulsion type dust oil which is bladeable and can be applied with a water wagon and spray bar. It is called Forest Service emulsion dust oil with a cost of approximately 6¼¢ per gallon at the refinery. The refinery is the San Pablo Oil Company in Martinez, California.

6. Q. Does Klamath County crush all cinders and, if so, what are the costs?

   A. Costs for crushing vary from 40 to 68¢ per cubic yard. This is a force account cost with no profit.

7. Q. How does weather affect a pumice road? What are haul costs compared between pumice and cinders?

   A. Weather does affect pumice, with some breakup and ruts in the winter and spring. Bly Logging Company feels it costs more to haul on cinders than pumice and watering costs are approximately the same for both surfaces.

8. Q. What is the recommended method for applying Arcadia Dust Oil to cinders?

   A. It is best to bring the cindered surface to a saturated condition with water prior to application of dust oil.

9. Q. Are there further comments on pumice roads?

   A. The best pumice road is a ditch. This is found to help maintain moisture in the subgrade but does create problems in the spring prior to frost leaving the ground. Forty years ago pumice roads were maintained with a drag behind a water wagon, which made a very satisfactory road.

10. Q. Will cinders degrade when used as a base course material?

    A. All materials will degrade, depending upon hardness, etc.

11. Q. In Weyerhaeuser's Surface Study, was it confirmed that in 2 years no surface loss had occurred?

A. Yes, that is what the study showed. Some surface loss was indicated when using surface levels due to the material being pushed down into the subgrade and compacted.

12. Q. Did Weyerhaeuser go back and give supplemental applications to dust oil treatments?

A. Yes; in some cases, but curves remained a problem.

13. Q. How many gallons of water does it take to maintain a pumice road per day in the summer?

A. Difficult to answer, but can handle 5 miles of road with one truck if water is handy. This would be approximately 16 loads per day.